Southwest Fisheries Science Center
Administrative Report H-94-03

WESTERN PACIFIC FISHERY INFORMATION NETWORK ISLAND DATA ASSESSMENT (WIDA) PROJECT:

SMALL-BOAT FISHERY SURVEY IN GUAM, 1980-91

Bert S. Kikkawa

Honolulu Laboratory, Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
2570 Dole Street, Honolulu, Hawaii 96822-2396

May 1994

NOT FOR PUBLICATION

ABSTRACT

Since 1978, the Guam Division of Aquatic and Wildlife Resources (DAWR) has monitored the island's small-boat fishery through offshore creel surveys. Surveys were composed of interviews of fishermen at Agana Boat Basin and island-wide, roving-participation counts; the surveys were conducted 4 days/month on 2 randomly selected weekdays and 2 weekends or holidays. To evaluate the survey design and the data collected (by season and method of fishing), the Western Pacific Fishery Information Network Island Data Assessment (WIDA) Project was initiated in 1992.

The WIDA Project applied data collected by the Guam DAWR in 1980-91 to examine trolling, bottomfishing, and spearfishing in Guam. The WIDA Project found that the number of trolling trips steadily increased because of the expanding number of charter and recreational boats. Mean daily effort increased from 8.25 to 22.5 trips/day on weekdays and from 18 to 56 trips/day on weekends or holidays. Catch rates, however, remained at about 4 kg/gear-hour and had no seasonal trend. Bottomfishing, on the other hand, was highly seasonal, with more effort expended during the summer months. Weekday effort by bottomfishermen remained at 5 trips/day, but weekend or holiday trips increased 92% (from 8 to 15 trips/day; overall mean, 11.4 trips/day). Mean catch rate was 2.25 kg/gear-hour but, in summer, was 5.0 kg/gear-hour. Boat-based spearfishermen were highly mobile and utilized all available launching sites around the island. During the study period, mean daily number of spearfishing trips was 3.0, and catch rate was about 7.5 kg/gear-hour.

The WIDA Project used a random sampling model to predict the number of survey days needed to estimate mean seasonal fishing trips and ratio estimator for catch rates at 10, 20, and 30% coefficient of variation (CV) levels for trolling, bottomfishing, and spearfishing. Both models used historical means and variances to predict current seasonal variances. The 1989-91 seasonal trip counts and catch rates were used in the model to predict the number of survey days needed to estimate mean daily seasonal trips and catch rates at the 20% precision level.

This analysis revealed that, for trolling, 2-9 survey days per season were required to estimate mean daily trips, and 1-6 survey days per season were required to estimate catch rates relative to type of day at the 20% CV level. For bottomfishing, 4-7 weekday and 7 weekend or holiday survey days were necessary to estimate mean daily trips and 2-17 survey days were necessary for estimating mean seasonal catch rates. For spearfishing, the number of survey days needed to estimate mean trips by season ranged from 2 to 7. However, 2-16 survey days were needed to estimate catch rates because of the highly variable daily catch rates.

The WIDA Project also evaluated the biological data collected during the surveys: species, length, weight, and fishing method and area. Predictive length-weight regressions were determined for 36 species of which 9 displayed allometric growth. Pelagic species were numerically predominant. Modal progression studies using length frequencies were made on three groundfishes, *Etelis carbunculus, Epinephelus fasciatus*, and *Lethrinus rubrioperculatus*. For the redgilled emperor, *L. rubrioperculatus*, growth constant (K) and asymptotic length (L_∞) were estimated as 0.286 yr^{-1} and 32.1 cm, respectively. Various surplus production models were used with catch and effort data; under equilibrium conditions offshore bottomfishing MSY was estimated to be 15,200 kg at 1900 h of effort; however, under nonequilibrium conditions results were inconclusive.

INTRODUCTION

The Magnuson Fishery Conservation and Management Act of 1976 designated the National Marine Fisheries Service (NMFS), an agency under the National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, to provide the best scientific information available to the newly formed regional fishery management councils. The councils were to use this information to develop fishery management plans (FMPs) for waters within the U.S. Exclusive Economic Zone. However, the information for FMPs under Western Pacific Regional Fishery Management Council (WPRFMC) jurisdiction was considered inadequate. Therefore, the Western Pacific Fisheries Information Network (WPACFIN) program[1] was formed in 1981 to organize, implement, and maintain fisheries information. The WPACFIN program has gathered fishery data on commercial landings through sales tickets from vendors and fishery coops and from creel surveys with offshore catch, effort, species composition, gear and area fished, and other ancillary information. This program has resulted in a marked improvement in collecting and processing of data to monitor fisheries resources, but its fishery data collection system has not been thoroughly reviewed in more than a decade (see CIC Research, Inc. 1983).

To evaluate the WPACFIN program's fishery data collection system, the WPACFIN Island Data Assessment (WIDA) Project was initiated in 1992. The project, in collaboration with fisheries officers of the Guam DAWR, assessed the present offshore creel survey design for estimating participation and catch-per-unit-effort (CPUE) for the three major fishing methods: trolling, bottomfishing, and spearfishing which together account for over 95% of the offshore fishery landings. Biological data collected during the creel surveys were evaluated, as were the commercial landing reports voluntarily provided by fishermen. This manuscript presents the WIDA Project's evaluation of the WPACFIN program's fishery data collection system in Guam during 1980-91.

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[1]Participating agencies in WPACFIN included American Samoa, Department of Marine and Wildlife Resources; Commonwealth of Northern Mariana Islands, Division of Fish and Wildlife; Guam Division of Aquatic and Wildlife Resources (DAWR); Guam Department of Commerce; State of Hawaii, Division of Aquatic Resources; NMFS Honolulu Laboratory and Pacific Area Office; and WPRFMC.

Study Site

Approximately 133,000 people inhabit the U.S. Island Territory of Guam (Guam Economic Research Center, 1991), which is the largest (550 km^2) and southernmost island in the Mariana Archipelago (lat. 13°30'N, long. 144°50'E). Guam is about 50 km long, 11.7 km wide, and 7.5 km at its narrowest part. The island is characterized by a high limestone plateau to the north that extends to a very narrow shoreline. The southern part of the island is marked by a ridge of high hills on the west coast and low rolling hills on the east coast. Unlike the northern half, the southern coast is not marked by clifflines and, except for a portion of the southwestern shoreline, is highly accessible to fishermen.

Guam's population centers in the north central portion of the island's western coast from the villages of Asan to Dededo which encompasses the capital city of Agana. This relatively small area contains about 56% of the population. With much of the shoreline in the northern part of the island inaccessible and harsh sea conditions to the east, Agana Boat Basin is the island's major small-boat launching site and has the greatest share of offshore fishing activity. The island boat-based fishery is highly mobile, and depending on the weather and fishing conditions, fishermen can trailer their boats to any launching ramp site on the island.

Fishing Seasons

One of the major factors influencing fishing activity on Guam is the temporal pattern of the weather. This pattern is constituted by four periods which are regulated by rainfall and winds rather than temperature variations. Rainfall divides the year into two periods: the "monsoon" season lasting approximately from late June through December and the "dry" season from early January through most of June. Additionally, the year can be divided into two wind condition periods: a time of fairly steady northeasterly winds or trade winds from October through March and the doldrums from about April through September.

The combination of wind and rainfall produces four noticeable seasons of fishing effort. Appropriately, the first season is designated as winter (January through March). Knudson (1987) reported this season as dry (average monthly rainfall, 12.7 cm), with comparatively steady northeasterly trade winds. However, bad weather and troublesome winds occasionally occur. Winter is considered good for inshore fishing because of the clear waters caused by low runoff from streams and rivers. Prevailing winds can produce offshore swells and infrequent minor storms, making this a fair season for offshore fishing. The second season, spring, runs from April to June. This season also is dry (average monthly rainfall, 19.1 cm), with relatively calm winds. These conditions produce good inshore and offshore fishing and the second highest season of fishing activity. The third season, summer, runs from July through September and is a time of light prevailing winds with increasing rainfall (monthly average, 33.0 cm). Although calm conditions prevail during much of the season, the chances of severe storms with typhoon intensity increase considerably. Despite the increased rainfall, summer ranks first in fishing activity. The fourth season, fall, is from October through December. This time of the year is marked by the return of the trade winds with relatively high rainfall (monthly average, 25.4 cm). The high occurrence of severe storms makes fall the poorest fishing season.

METHODS

Guam's offshore fishery is described as fishing activity involving the use of a boat. Fishing typically occurs on the west side of the island (Fig. 1), usually outside the reefs and reef flats. For portions of this study, the boat-based fishery has been categorized by area fished (i.e., nearshore areas and offshore banks) to account for differences in the nature and purpose of fishing. Area stratification improves the relationship between true fish abundance and CPUE; a good relationship between abundance and CPUE is essential for surplus production modeling. Nearshore fishing usually is conducted 1.7-3.3 km (1-2 miles) from shore by recreational and weekend fishermen. Offshore banks include Rota Bank to the north and Galvez and Santa Rosa Banks to the south. These banks are about 33.3 and 58.3 km (20 and 35 miles), respectively, from the island (Fig. 1) and are typically frequented by commercial and more experienced fishermen. A high proportion of the boats in the offshore fleet are <9.1 m (30 ft) long and powered by an inboard or outboard motor; a few powered boats are 12.2-15.2 m (40-50 ft) long. Most boats are trailered and usually take 1-day trips. The most commonly used launching sites are Agana Boat Basin and the newly opened Agat Boat Basin. Guam's current offshore fishery is diverse and complex and includes several fishing methods: trolling, shallow and deepwater bottomfishing, spearfishing, atulai (bigeye scad) fishing, longlining, and netting.

Data Collection and Analyses

The WIDA Project evaluated the design of the fishery data collection system used by the Guam DAWR. Since 1978, the Guam DAWR has conducted creel surveys to monitor offshore fishing activities primarily to detect trends in catch, fishing effort, area fished, and species composition by the various fishing methods. The surveys also have been used to estimate total annual catch and effort by the boat-based, offshore fishery. Offshore creel surveys were conducted monthly on 4 randomly selected days, 2 of which were weekdays (WD) and 2 were weekends or holidays (WE/H). For each survey day, a surveyor randomly interviewed fishermen returning to Agana Boat Basin during 0500-1100 and 1615-2345. Agana Boat Basin is adjacent to Guam's business district and holds slips and moorings for 36-41 fishing boats and 14 charter boats. The surveyor acquired information on species composition, method of capture, time spent fishing, number of gear units and persons fishing, area fished, total weight of the catch, and, if possible, individual fish weights and lengths. Ancillary information included prevailing weather conditions and economic information (Fig. 2). While the creel surveys were being conducted, island-wide offshore participation was estimated by a roving surveyor who counted all attached trailers at public boat launches. The surveyor adhered to a strict timetable on a predetermined route. Morning and evening circuits were taken in similar tracks but alternated between similar day types (e.g., if the first WD and WE/H circuits were clockwise, the subsequent WD and WE/H circuits were counterclockwise).

Using the data collected during the surveys, the WIDA Project regressed fish weights (pounds) to fork length (centimeters) by a power function and linearized by logarithmic transformation of both variables. Thereupon, condition indices were estimated for 18 species and compared with earlier works by Ralston (1988). Ponderal index, condition index, or K factor can be expressed as

$$K = \frac{W}{L^3}\ , \qquad (1)$$

the ratio of body weight (W) over linear body dimension (L). Progressive modal analysis was used on the size frequency data to estimate von Bertalanffy growth constants, K and asymptotic length, L_∞, for the redgilled emperor, *Lethrinus rubrioperculatus*, the ehu, *Etelis carbunculus* and the banded grouper, *Epinephelus faciatus*. Because the data collected at any one time were insufficient for monthly or season studies, size frequency data were pooled over the year, smoothed by a moving average of five, and evaluated.

Total instantaneous mortality rate was estimated for the three fishes based on length-converted catch curves by two independent methods: the exponential decay method and the Wetherall et. al (1987) method. Length frequency distributions were separated into modal components by fitting a distribution mixture model developed by Macdonald and Pitcher (1979) which were assumed to be year-class components. These modes were clearly defined such that the 1986 cohort could be tracked through the 4-year time series, from recruitment into the fisheries to near maximum size. With the exponential decay method total mortality was estimated by regressing the logarithm of relative abundance for the 1986 cohort over the four years; the rate of change or slope of relative abundance estimates mortality. With this model, it is not necessary to assume that natural and fishing mortality remain constant during the entire lifespan of the cohort. The regression estimator of Wetherall et al. (1987) method, a modification of the Beverton and Holt *Z*-equation based on length data, assumes equilibrium conditions in the *Z/K* ratio estimation. Parameters were estimated by regressing the mean length (l_i) of all fish $\geq l_{ci+1}$, where l_c is the first size class that was fully selected by the fishery to the largest length category. The *Z/K* ratio was estimated by $Z/K = B/(1-B)$ where B is the slope of the regression.

Catch and effort data for trolling and bottomfishing were applied to surplus production models. For a better relationship between fishing effort and abundance, trolling and bottomfishing methods were partitioned into offshore-bank and nearshore fisheries. Preliminary estimates of bottomfish yields were made from annual CPUEs, and MSY estimates were obtained for both equilibrium (Schaefer 1954 and Fox, 1970) and nonequilibrium conditions (Schnute, 1977). The Schaefer model expressed CPUE as a linear function of effort, $Y(i)/f(i) = a + b\ f(i)$ if $f(i) \leq -a/b$. The slope, b, must be negative if (Y/f) decreases for increasing effort. Fox (1970) modified the Schaefer model by having the logarithm of CPUE effort (Y/f) as a linear function of effort, such as $\ln(Y(i)/f(i)) = c + d(i)$. Schnute (1977) used a regression method to transform the Schaefer model into a dynamic approach, thus eliminating equilibrium assumption.

Island-wide Fishing Activity Estimates

Daily island-wide fishing activity for the major fishing methods were estimated by extrapolating the fishing activity out of Agana Boat Basin. On each creel survey day proportionality constants, p_1 and p_2, are determined from the interview data, island-wide participation counts and other ancillary information collected during the creel survey and roving census counts. The proportionality constant p_1 was the probability of interviewing a fisherman involved in a particular fishing method and returning to Agana Boat Basin within the allotted interview period. And p_2 was a proportion of the island-wide fishing activity originating from Agana Boat Basin. Thus, island-wide activity was estimated by dividing the number of trips for each method out of Agana Boat Basin by its respective *p* values. These estimates assume that the proportion of each fishing method to the day's overall fishing activity at Agana Boat Basin is similar for the rest of the island. This assumption may no longer be true because of the increasing number of charter boats and the opening of the Agat Boat Basin on September 15, 1990. The present Guam DAWR-WPACFIN Program expands mean daily fishing activity and CPUE to estimate monthly and annual totals.

To evaluate the island-wide fishing activity estimates, the WIDA Project first examined the means and variances of the daily fishing trip counts relative to the season and percentage of the island covered by the interviews on WD and WE/H. Initial monthly analysis by the WIDA Project of fishing trips means and variances indicated that the number of WD and WE/H trips were significantly different within each month. Overall, mean fishing activity counts on WD were significantly lower ($\bar{y}_{WD}$ = 20.3, SE = 0.877) than on WE/H ($\bar{y}_{WE/H}$ = 45.0, SE = 1.155), thus monthly counts could not be pooled and thus evaluated accordingly by WD and WE/H. With the current survey timetable of 2 WD and 2 WE/H per month, sample size would be the minimum necessary to estimate monthly variance. Therefore, to increase sample size, offshore fishing activity was analyzed by season and day type for the three fishing methods. Monthly examinations of within day type and among day type catch and effort variance showed no significant difference between the monthly means. Thus, catch rate data were pooled across months for each day type and analyzed by season for the three major fishing methods.

Sample Size Determination

One major objective of the WIDA Project was to establish guidelines for determining the number of sampling days required to estimate mean daily fishing activity and catch rates for trolling, bottomfishing, and spearfishing. Such guidelines are necessary because oversampling consumes valuable resources, and undersampling lowers the precision of the results. Sample size guidelines for estimating catch, effort, and participation were determined by examining the historical data from the creel surveys conducted in 1980-91. Guidelines were developed by using three levels of precision, 10, 20, and 30%, to estimate daily fishing activity and CPUE. Relative precision was measured as the coefficient of variation (CV) of an estimate:

$$CV(x) = \frac{SE(x)}{x} \cdot 100 \,, \qquad (2)$$

where x is the estimated participation, effort, or catch; $SE(x)$ is the standard error of the estimate. Precision levels of 10 and 30% were selected as upper and lower limits to the current survey sampling precision standard of 20%. Sample size determination with random sampling is given by the formula:

$$n = \frac{s^2}{CV^2\,\overline{x}^2} \,, \qquad (3)$$

where CV is the desired level of precision expressed as a proportion, s^2 is the population variance of the variable to be measured, and $\bar{x}$ is the estimated mean (Elliot 1971; Cochran 1977). With Equation (3), the variances can be replaced by an empirically determined function of the mean as described below. Thus, sample size can be calculated by substituting an approximate value for the expected mean.

The variance-mean relationship was determined by regressing the logarithm of within-season variance against the logarithm of mean seasonal activity for each of the fishing methods by WD and WE/H. Therefore, from these relationships the determined functions of the means can be integrated into Equation (3), and sample size determinations can be presented graphically at precision levels of 10, 20, and 30% for the three fishing methods by WD and WE/H and season. Each isopleth estimated the number of sampling days needed in a season to obtain the appropriate precision levels for a range of daily means.

In this study two statistical estimators were used to calculate mean seasonal catch rates for each fishing method. The first considers a survey day as a sampling unit and the total amount of fish caught divided by total gear-hours expended for the day approximates catch rate. Mean seasonal catch rate, $\bar{r}$ was defined as

$$\overline{R_j} \cong \overline{r_j} = \frac{\displaystyle\sum_{h=1}^{m_j} \left(\frac{\sum_{i=1}^{n_{jh}} C_{ihj}}{\sum_{i=1}^{n_{jh}} f_{ihj}} \right)}{m_j}, \quad (4)$$

where m_j is the number of survey days in season j and $\overline{r_j}$, the mean seasonal catch rate. Catch, (C_{ihj}) and effort, (f_{ihj}) were summed over ith interviews for each hth survey day.

The second used the ratio estimator to calculate mean seasonal catch rate and defined as

$$\overline{R'_j} \cong \overline{r'_j} = \frac{\sum_{h=1}^{m_j} \left(\sum_{i=1}^{n_{jh}} C_{jhi} \right)}{\sum_{h=1}^{m_j} \left(\sum_{i=1}^{n_{jh}} f_{jhi} \right)}, \quad (5)$$

where C_{jhi} is the sum of the catches over ith interviews and hth survey day in the jth season. Although variance for the first estimator can be determined through the standard variance formula, the mean daily catch rate is considered a seasonal observation. The variance of the ratio estimator (Mendenhall et al., 1971), $\bar{r}_i$' was calculated by

$$V(\bar{r}_j) = \left(\frac{N_j - n_j}{n_j N_j}\right)\left(\frac{1}{u_{f_j}^2}\right)\frac{\sum_{i=1}^{n}(C_{jhi} - r_j f_{jhi})^2}{n_j - 1}, \qquad (6)$$

where N_i is the total number of trips in a season, n_i, the number of interviewed trips in a season, and r_i, the mean seasonal catch rate for each day type. Because the population mean effort, u_f, is unknown $\bar{f}^2$ can be used to approximate u^2_f in the equation. Catch rates were evaluated over day types and the variance-mean relationship determined by regressing logarithm of variance against the logarithm of the seasonal catch rate for each of the fishing methods. Initial examinations of catch rates and associated variances between WD and WE/H and within-season have shown no significant differences between type-day for each of the fishing methods, although catch rates on WD were higher. However, analysis of catch rates was made according to day types. By integrating the empirically determined function of the mean to variance into Equation (3), sample size determinations could be presented graphically at precision levels of 10, 20, and 30% for the three fishing methods and by season and type of day. Each isopleth estimated the number of sampling days needed in a season to obtain the appropriate precision levels for a range of daily means.

In addition to overall CPUE, catch rates of the five major trolling caught species: mahimahi (*Coyphaena hippurus*), wahoo (*Acanthocybium solandri*), skipjack tuna (*Katsuwonus pelamis*) and yellowfin tuna (*Thunnus albacares*), and Pacific blue marlin (*Makaira nigicans*) were examined. Individual catch rates were analyzed to determine the number of survey days needed to estimate mean specific catch rates for the five major trolling caught species. Individual catch rates were pooled over day types and variance-mean relationship determined by regressing logarithm of variance against the logarithm of mean catch rate for each season. Empirically determined functions of the mean were integrated into Equation (2), sample size determined at 20% precision level for each species and season.

RESULTS

During the study period, length-weight data were collected from 1,188 individuals and 36 species; however, only 22 species had ≥10 individual observations (Table 1). Of the sampled fishes, trolling-caught fishes were predominant, followed by shallow-water bottomfishes. Skipjack tuna and mahimahi combined represented about 41% of the sampled fishes and individually accounted for 23% and 22% of the total estimated landings, respectively. Of the many bottomfish species taken around Guam, the redgilled emperor or mafuti accounted for about 20% of the total bottomfish landings. The mafuti can be found on sandy and rubble substrates along the outer reef slopes at >12 m depths (Myers 1989) and considered as a shallow-water bottomfish.

Additionally, mean condition indices of 18 species were estimated and 2 of which, *Pristipomoides zonatus* and *P. auricilla*, were compared and found to be higher than those in Ralston's (1988) (Table 2). Since no variance estimates were included in Ralston's study, statistical comparison of the means could not be made. However, in our work both species exhibited isometric growth although survey-sampled fishes were of a narrower size range (by 2 and 4 cm at the lower and upper bounds, respectively).

The most comprehensive bottomfish length frequency data were collected from the redgilled emperor. Sizes sampled ranged from 10-40 cm fork length (FL), with highest catches in the 20- to 30-cm FL range. From 1987 to 1991 a total of 1,294 lengths were gathered and analyzed. During the 5-year period, an annual average of 259 length measurements was taken which appears to be minimal for the length-based analysis for the redgilled emperor. The progressive modal analysis resulted in estimates of growth parameters K and L_∞ as 0.286 yr^{-1} and 32.1 cm FL, respectively. And estimated total mortality, Z for the 1986 cohort as about 0.57 yr^{-1} (SE = 0.1205) from the exponential decay method. With the Wetherall et al. (1987) method and applying the estimated K value of 0.286 yr^{-1}, total annual mortality estimates ranged from 0.386 in 1989 to 0.782 in 1987 (Fig. 3), with an overall mean of 0.59 yr^{-1} (SE = 0.0314). Two other commonly caught bottomfish species, *Pristopomoides zonatus* and *Epinephelus faciatus,* were examined, but the results were inconclusive because of insufficient length data. From 1986 to 1991 annual number of length observations averaged about 45 and 85 for *P. zonatus* and *E. faciatus*, respectively.

Preliminary estimates of bottomfishing MSY from offshore banks with the surplus production models under equilibrium conditions were 15,200 kg with about 1,900 h of effort and 14,000 kg at 2,700 h of effort from Schaefer and Fox models, respectively. Highest estimated annual bottomfishing landings from offshore banks were 10,600 kg which was about 4,600 kg and 3,400 kg below the respective MSY estimates. Initial results of the production model under nonequilibrium conditions were inconclusive. Trolling catch/effort-abundance data are yet to be analyzed.

Fishing Activity and Catch Rate Estimates--Sample Size Guidelines

Fishing activity, number of daily trips on WE/H was twice that of WD trips: 15.18 and 7.86 mean daily trips, respectively (Table 3). Participation was highest when more than 50% of the fishing activity originated from Agana Boat Basin (about 65% of the time). Mean participation counts for both WD and WE/H were positively related to p_2 values; mean number of WD trips averaged 4 when p_2 <0.25 and 9 trips with p_2 >0.50. Similarly, on WE/H, the number of boat trips increased (from 4 to 19) as proportionately more fishing activity originated from Agana Boat Basin.

Variance-mean relationship patterns of fishing activity were similar for each of the fishing methods. When the logarithm of mean number of daily fishing trips was low (<5 trips/day), log-variances tended to equal the means. At higher activity levels, variances were greater than the means, and slopes were positive (Table 4). The positive relationships suggest that the variance-mean relationships can be described by a negative binomial model and the variance can be determined by:

$$s^2 = \overline{A} + \frac{\overline{A}^2}{k} , \qquad (7)$$

where s^2 is the variance, $\overline{A}$ is the mean and k is the exponent in the negative binomial series. The reciprocal of the exponent k, $(1/k)$, is the measure of the excess variance or clustering of the individuals in a population (Elliot 1971). The variance-mean relationships were examined for all three major fishing methods with regard to type of day (WD and WE/H). Although the variance-mean ratio often exceeded 1 and thus indicated a negative binomial distribution; a random distribution model offered a more parsimonious description of the relationship. Both models were applied to the variance-mean relationships, and the number of sample days for each method was estimated through each respective model. However, only estimated sample days from the random model were presented in a graphic form.

Mean seasonal catch rates were similar from both the random sampling and ratio estimators; however, variance estimates from the ratio estimator were lower for each method and day type (Table 5). As a result, sample size estimates from the ratio estimator were lower. Estimates of $\bar{r}$ and $\bar{r}'$ and associated variances varied widely between season and day type for each fishing method. Variance-mean relationship patterns of catch rates were similar for both r_i and r_i'; variances tended to be positively related to the means for each of the fishing methods.

Additionally, catch rates from five major species caught by the trolling method were analyzed to determine the number of sampling days required to estimate mean seasonal specific catch rates at 20% precision level. Similarly, a random model was used to describe the variance-mean relationship.

Trolling

From 1980 to 1991, the mean number of daily trolling trips increased threefold from 8.25 to 22.5 on WD (α_{WD} = 7.17, β_{WD} = 1.30, P $\leq$ 0.001) and from 18 to 56 on WE/H ($\alpha_{WE/H}$ = 13.123, $\beta_{WE/H}$ = 3.66, P $\leq$ 0.001). Trolling trips were significantly higher on the WE/H than on WD (F = 16.01, P $\leq$ 0.007), with no apparent seasonal trend. Fishing activity occurred randomly: Indices of dispersion were close to 1 over the entire island during WE/H or when 25-75% of the trolling activity originated from Agana Boat Basin. However, during WD or when <25% or >75% of the trolling activity originated from Agana Boat Basin, fishing activity appeared to be clustered. The variance-mean ratio was >1 due to clustering effects of fishing under favorable conditions of weather and higher catches.

Overall, annual trends in trolling effort declined from 6 to 4.25 h/trip; however, the mean number of persons per trip doubled from 2.5 to 5. Through the years the number of trolling trips to areas immediately around Guam increased fourfold from about 2,700 to 12,000, whereas trips to the adjacent offshore banks declined about 50% from about 1,500 to 780 (Fig. 4). Mean fishing effort remained at about 7.8 h for offshore bank trips and declined slightly from 5 to 4 h for nearshore trips. Because of some uncertainty in the designation of area fished the number of nearshore trips can be upward biased.

Figures 5-8 present the sample-size guideline formula at precision levels of 10, 20, and 30% for WD and WE/H. Each isopleth shows the relationship between the number of sampling days and seasonal mean daily trolling trips and presents a quick method for estimating seasonal mean daily trips at the three appropriate precision levels. For instance, the mean participation count on WD in winter for the last three years, 1989-91 was 23.5; thus, 7 survey days were required for both negative binomial and random models to estimate daily mean trips at the 20% precision level (Fig. 5). However, for a WE mean of 59 trips, 3 survey days were needed for 20% precision level from the random model, and as a comparison with negative binomial model, 5 survey days were needed. For each season and day type, Table 6 shows the mean participation counts for 1989-91 and the required number of survey days at the 20% level of precision.

Although WD and WE/H trolling catch rates were not statistically different, trolling catch rates were examined and evaluated by day type. Annual CPUE trends remained relatively constant at about 3.0 kg/gear-hour for all seasons, except in fall which showed a declining trend with an overall mean of 2.0 kg/gear-hour. Trolling catches were highest for mahimahi in winter and spring, skipjack tuna in spring, and yellowfin tuna and Pacific blue marlin in summer. Spatially, catch rates were higher in summer at areas immediately around Guam; however, winter catch rates were highest at the offshore banks. During the study period, the number of fishing trips to nearshore areas increased more than by 400%; this resulted in a drop in catch rates (from 3 to 1 kg/gear-hour). There was also a 333% increase in the number of zero-catch trips (from 570 to 2,471/year). Although trips to offshore banks declined, catch rates and zero-catch trips remained constant at 4.0 kg/gear-hour and 5 trips/year, respectively.

From simple random sampling the estimated number of survey days needed for a 20% precision in estimating 1989-91 mean catch rates for each season and day type varied from 6 to 16 days. Mean catch rate from 1989-91 ranged from 1.5 kg/gear-hour in fall to 4.2 kg/gear-hour in winter. Because of the lower variances from the ratio estimator the number of survey days in turn was lower (1 to 6 days) (Table 7). These figures are less than the current level of 6 WD and 6 WE/H sampling days per season. Figures 9-12 represent the relationship between mean catch rates from the ratio estimator to the number of survey days at the 10, 20, and 30% precision levels.

During 1989-91 mean mahimahi catch rates ranged from 0.24 in the summer to 1.84 kg/gear-hour in the winter. Therefore, the number of survey days needed to estimate seasonal mahimahi catch rate at the 20% precision level ranged from 22 to 56 in the winter and summer, respectively. These estimates increase 120-300% the number days needed to estimate overall catch rates by trolling method. For yellowfin tuna the number of survey days needed to estimate specific catch rates ranged from 17 to 43 days at the 20% precision level for the summer and fall, respectively. Table 8 shows the number of surveys days needed to estimate specific catch rates at the 1989-91 mean CPUE.

Bottomfishing

Bottomfishing in Guam was seasonal. Effort was highest during summer, with mean daily trips of 7 on WD and 15 on WE/H. Mean number of bottomfishing trips on WD ranged from 4 in spring and fall to 7 in summer, while mean daily bottomfishing trips on WE/H ranged from 9 in winter to 15 in summer.

During the study period, mean daily bottomfishing WD trips remained relatively unchanged (mean, 5 trips/day). However, trips on WE/H increased an average of 90%, from 8 to 15. The largest increase in fishing effort occurred in spring with a 183% rise from 6 to 17 mean daily trips. Annual estimated bottomfishing trips to nearshore areas increased from about 450 to 2,300 trips while trips to offshore banks remained constant at about 300 trips/year (Fig. 13).

Figures 14-17 present bottomfishing trip sample-size guidelines at precision levels of 10, 20, and 30% for WD and WE/H through a random model. Each isopleth estimates the number of sampling days required in a season to obtain the appropriate precision levels for estimating mean daily bottomfishing trips. As the mean activity increased, the number of sampling days decreased for each CV level. From Equation (2), the number of survey days was estimated by using the mean daily bottomfishing trips by season and day type from 1989-91. In winter, there was an estimated mean of 7.4 bottomfishing trips/WD; therefore, based on the sample-size guidelines, 5 survey days were needed to have 20% precision through both models (Table 9). WE/H averaged 11.9 bottomfishing trips during the winter; thus, about 7 and 29 survey days were necessary from the random and negative binomial models, respectively.

Like trolling, bottomfishing catch rates on WE/H were not significantly different from those on WD (t = 0.882, $P \leq 0.386$). Seasonal catch rates from 1989-91 ranged from a low of 1.2 in fall to a high of 4.42 kg/gr-hr in the winter, and through the years seasonal catch rates remained relatively unchanged. Increased pressure on the nearshore bottomfish resources resulted in a 50% drop in catch rates from 3.0 to 1.5 kg/gr-hr and an annual average of 76 zero-catch trips. Catch rates from offshore banks remained unchanged at about 5.0 kg/gr-hr and an estimated 8 zero-catch trips/year. The nature of bottomfishing trips did not change and usually involved about 3.75 persons on a 3.75- to 4.25-h trip with a mean effort of 12 gear-hours.

Figures 18-21 show bottomfishing catch rate sample size guidelines at precision levels of 10, 20, and 30%. Each isopleth estimates the number of sample days required in a season to obtain the appropriate precision levels for estimating mean daily catch rates. As catch rates increased, the number of sampling days decreased with each of the three CV levels. Based on the 1989-91 bottomfishing catch rates the number of seasonal surveys needed to estimate the mean seasonal catch rates within the 20% CV ranged from 2 to 17 (Table 7).

Spearfishing

Offshore, boat-based spearfishing activity was independent of season and type of day; more trips were taken in summer on WD (mean = 5.11) and in the winter on WE/H (mean = 4.37). On WD, the mean number of trips commonly varied from 1.5 to 6.7. On WE/H, spearfishing trips ranged from 1.3 to 9.4.

Based on the mean number of trips by season and day type during 1989-91, Table 10 presents the number of survey days necessary to estimate participation at the 20% precision level.

Similarly both random and negative binomial models were use to determine the number of sample days needed to estimate the 3-year means. Mean number of survey days to estimate mean daily spearfishing trips on WD and WE/H from the random model were shown in figures 22-25.

Through the year spearfishing catch rates remained fairly constant at about 5.0 kg/h during fall and winter; however, in summer, catch rates jumped twentyfold from 0.5 to 10 kg/h. In comparison, spring had a relatively moderate increase from 2 to 10 kg/h. The increases in spring and summer can be attributed to better diving conditions. Figures 26-29 show the number of survey days required to estimate mean seasonal spearfishing catch rates. Number of survey days needed to estimate the 1989-91 mean catch rates by season and day type ranged from 2 to 16. In general, variances with the ratio estimator were lower on WD; thus, fewer survey days were required (Table 7).

DISCUSSION

Out of the many possible paths to be taken, the WIDA Project tried to understand species population dynamics for fishery management through age and growth studies. Besides age-specific parameters such as mortality and fecundity, other information can be derived from detailed age and growth studies to include population structure description, determination of timing and frequency of spawning, individual and population growth responses to environmental changes such as population density or changes in the habitat, and recruitment success. These data with other biological information are directly applicable to fishery management; i.e., slow-growing fishes are less likely to withstand as much exploitation as a population of fast-growing fishes.

The WIDA project initial attempts to understand specific age and growth parameters were through size frequency-modal progression method. Although it is time consuming, requires a minimum amount of observations in a decided time period, and is most often confined to more common species, it requires minimal technical skills, no elaborate equipment, and is relatively easy to obtain ensuring that under the right circumstances survey collected catch data can be the basis of age and growth analysis. Annual collection of size frequency data on *L. rubrioperculatus* from the survey interviews was satisfactory for modal progression studies and resulted in reasonable growth and mortality estimates. Otolith studies by Ralston and Williams (1988) on the redgilled emperor from American Samoa estimated growth rate as 0.216 yr^{-1} and L_∞ as 30.8 cm FL. Their results were not significantly different from those caught around Guam (t = 0.643, df = 10). Based on the t_0 estimate of -0.4 yr by Ralston and Williams (1988), redgilled emperor in Guam would be about 4.4

years of age when they become fully vulnerable to the fishery at about 24 cm FL. Estimates of *Z* for the redgilled emperor were about 0.57 yr^{-1} and 0.59 yr^{-1} (the 1986 cohort) from the exponential decay and Wetherall et. al. method (1987), respectively. If total mortality is assumed to be about twice that of *K*, growth constant, estimates from both methods appear reasonable. Although there were no studies on pelagic species, collected length frequency data appear to be reasonable for specific-age and growth studies. Specific trolling catches were highly seasonal; consequently, size sampling should be concentrated in a relatively short period for modal progression studies.

From a myriad of fish age and growth methodologies in the literature, the WIDA project recommends (besides statistical approach to modal progression in a time series) direct measurements of growth in certain individuals and extrapolating to the population such as mark and recapture, growth confinement, or age estimates based on fine periodic markers on hard structures for the more uncommon species. Also, another alternative is the use of "shortcut" methods (Pauly, 1979, see Appendix A) to produce certain parameter values when the commonly used primary data are lacking.

An alternative to a multispecies fishery in which each species has an interaction with each other is to aggregate species and treat the total as a stock. In a tropical multispecies fishery, any fishing gear is capable of catching a variety of species that differ in behavior, spatial and temporal distribution, species interaction, and market price of the catch. Where and when fishermen choose to put a hook in relation to species distribution and how they operate their gear dictate the catch of a given species. Such choices will be determined by species abundance and market price; thus, CPUE of any one species may not be a reliable estimate of another species. Traditionally, fishery science has treated each species and stock as an entity for analysis and management. Production models using CPUE and effort are the simplest stock assessment models; however, their popularity has declined in favor of age-structured models. The poor standing of production models is often due to the failure to estimate optimum effort or maximum sustainable yield (MSY), resulting in a poor contrast between fishing effort and stock abundance (Hilborn, 1979). Overall, production models ignore the complexities of age structure, spatial structure, and so on and use a single number to describe population biomass. Production models are frequently used in fisheries where catch-at-age data are difficult to obtain. Their use in formulating FMPs depends greatly on the nature of the available data. Because biomass is rarely measured directly, almost all applications of biomass dynamic models use an index of abundance (CPUE), and estimation procedures are complex and highly model dependent. However, it is necessary to identify changes in fishing practices and techniques, fish abundance or distribution of fish, or fishing that can make CPUE a biased estimator of changes in abundance. Initial aggregate CPUE data analysis via the production model resulted in MSYs of 15,200 kg and 14,000 kg from offshore banks bottomfish fishery and an spurious yield estimate for the nearshore fishery. Estimated MSY was about 43% and 32% above the estimated peak total bottomfish landings of 10,600 kg from offshore banks. Hilborn and Walters (1992) emphasized that equilibrium methods frequently overestimate surplus production and optimum effort whenever they are applied to data gathered during a stock decline (e.g., during fishery development) and also stocks are never in equilibrium.

Results of surplus production model on nearshore bottomfish fishery were inconclusive possibly from the increased variability of catch/effort in the later years indicating probable departure in the CPUE-abundance relationship and resultant failure of the model. The variability is the result of the recent changes in the fishing fleet and improvement and openings of other boat basins around the island.

In the examination of island-wide daily fishing activity it was essential to understand the spatial distribution patterns of the boats for effective statistical analysis of the data. There have been many different proposals for indices to compare the different dispersion patterns in the population; however, there is no coefficient which is best for all possible cases for the measure of non-randomness (Elliot, 1971). In this study the variance-mean ratio was used to test for departure from randomness and for most cases the distribution of fishing activity appears to be positively contagious, reflecting the clustering nature of fishing. In the process of determining the number of sampling days required to estimate mean daily fishing trips, both random and negative binomial models were included in the analysis of which the latter produced higher estimates. The number of survey days for estimating mean daily trolling trips was similar between random and negative binomial models; however, for both bottomfishing and spearfishing methods the negative binomial model increased the number of survey samples days by 153% and 477%, respectively. These estimates appeared to be upward biased because of the smaller sample sizes and higher variances from both fishing methods. Green (1966) indicated that coefficient of nonrandomness should not be calculated from a small set of samples, particularly when variance is high which tend to be positively contagious.

During the study period, nearshore trolling activity has been steadily increasing since 1984, while the number of trips to offshore banks have been declining. In the past, when nearly all fishing boats originated out of Agana Boat Basin, monitoring island-wide fishing activity was possible by sampling only one port. However, with the recent changes in the fishery and along with the addition and improvement of other launching sites it is unclear if fishing activity out of Agana Boat Basin is representative of the island-wide activity. Because of the development in the charter boat industry at Agana Boat Basin, often with two or more fishing trips daily, trolling activity out of Agana Boat Basin overrepresents island-wide daily trolling fishing activity especially on WD and should be standardized in the annual participation estimating process. Charter boats are larger than the typically trailered boats and normally make two 4-h trips daily to nearshore fishing grounds. Ninety percent of the sportsfishing charter fleet is berthed at Agana because of its proximity to the major hotels. Agana Boat Basin is too small to meet the current demand and has a long waiting list for space. As of December 1990, Agana has about 12-14 full-time charter boats and berthing for 50-55 boats. It also has 2 boat launching ramps and space for about 40 trailers. In September 1990, Agat Boat Basin, which holds slips and moorings for 153 boats, was opened; however, because it is farther from the hotels, few charter boats are berthed there (Gaffney, 1991).

Part of the WE/H increase (127%) in trolling activity at Agana Boat Basin was caused by increasing numbers of recreational fishermen and demographics. The increase appears to be biased and not indicative of the other launching sites which are located in rural Guam. As a result of the increasing fishing effort nearshore trolling catch rates have been declining and without any estimates of abundance WIDA project can only surmise that the pelagic stocks around Guam are being impacted heavily.

In this study two approaches were taken to estimate mean seasonal catch rates which had very similar results; however, variance estimates from the ratio estimator were lower. Relative efficiency, variance ratio of simple random sampling over the ratio estimator, was used to compare variances between the two estimators (Cochran, 1977). A higher relative efficiency resulted from the ratio estimator because of its lower variance estimates. In determining the number of survey days for estimating mean catch rates the ratio estimator was preferred because of the higher relative efficiency.

The number of survey days to determine the 5 trolling caught species catch rates at the 20% precision level averaged 74 days in the winter and 34 in the other seasons, an increase of 7.4 and 2.6 times as many days. Although there was no analysis on either bottomfishing or spearfishing, specific catch rate slopes for the variance-mean relationships should be very similar or greater, and consequently, the number of days to estimate specific catch rates from both methods should be equal or greater in magnitude.

Like trolling, the rise of bottomfishing activity on WE/H can be attributed to the increasing number of recreational bottomfishermen; however, because full-time and part-time commercial fishermen who are primarily responsible for the WD activity number of WD bottomfishing trips remained relatively unchanged. Commercial fishermen avoided WE/H because of increased activity on the fishing grounds and potential disclosure of favorite fishing spots. Through the years catch rates on nearshore fishing grounds have been dropping. The lower catch rates can result from increasing effort, lower stock abundance, and novice fishing skills of the recreational fishermen who typically fish nearshore. Catch rates from the offshore banks have remained relatively steady because of the relatively lower impact on the bottomfish resources. A large number of fishermen from Agana Boat Basin typically fished the areas nearshore and banks north of Guam, and for many of the trips to southern banks the Merizo launching ramp was favored because it offered a shorter run to the fishing grounds. In recent years Guam DAWR sampled Merizo offshore fishery once a month; although results were not included in this study bottomfishing catch rates were reportedly higher (R. Myers, DAWR pers. comm.). Because Agana Boat Basin was the only port included in the survey, it is again questionable if estimates of island-wide bottomfishing activity based on activity counts for Agana Boat Basin are indicative of the entire island. For instance, from 1980 to 1991 WPACFIN estimated that the number of boats bottomfishing increased 621% from 24 to 173 (Bottomfishing PMT Report 1991); however, the increase in survey trip counts was only 200%.

Of the three major fishing methods, spearfishing had the lowest activity rate. Because of spearfishermen's irregular fishing habits, it is unclear whether spearfishing activity was adequately represented. Spearfishing can occur day or night and both inside and beyond the reefs. Spearfishermen are traditionally highly mobile and very selective of diving conditions and location. With the current creel survey design, chances of interviewing returning spearfishermen at Agana Boat Basin are very small.

RECOMMENDATIONS

During the 1980-91 study period the Guam fishery had experienced some changes, and although some of these changes have been moderate through the years, accounting for the changes is necessary for some of these studies. Because the current offshore survey site at Agana Boat Basin is insensitive to the changes in the small-boat fishery (e.g., the increasing number of charter boats and the effects of having new or improved launching sites), stratified random sampling among the three major launching sites (Agana, Agat, and Merizo) is recommended by the WIDA Project to produce better island-wide estimates of catch rates and participation for each type day, method, and season. Because of the paucity of monthly samples and because variance estimates are necessary (the number of sampling units must be >1.[2]), only seasonal estimates by day type and fishing method could be developed from the survey data. Unless the number of monthly survey days increases by at least threefold, only seasonal estimates are possible. On the other hand, seasonal stratification conform to the natural climactic conditions of the island.

In a multispecies fishery where catches and landings include a large number of species with few specimens of a single species, collecting enough size frequency data for any one species for modal analysis in a time series is often very difficult. This is especially true for many of the bottomfish species. Under the right circumstances size frequency data from the offshore creel survey can be supplemented through a rigid market sampling program. With such a program, additional size frequency and other biological data can be obtained on nonsurvey days which, based on the current sampling schedule, happens on 90% of WD and 75% of WE/H.

For many of the primary fishery management species around Guam, size at first maturity and spawning season are yet to be determined. Because fishermen are reluctant to have their fish sampled and sexed prior to market, biological samples necessary for maturity studies could be obtained from the markets provided the discarded viscera contains gonads from identified whole fish. Outright purchases could be another way of obtaining the much-needed biological samples for smaller-sized fishes. Sexual maturity and spawning season can easily be determined with relative gonad weight or gonadosomatic index (GSI = 100 * gonad weight/body weight). The GSI, however, does not reliably indicate maturation stages which can be obtained through visual assessment of the ovary during spawning season.

Size at maturity is invaluable in stock recruitment analysis as it relates recruit numbers to parent stock size and not to overall standing stock; thus, it is necessary to separate the size of the stock to those above size or age at maturity. Both overall standing stock and parent standing stock are directly proportional by a coefficient that can be determined mathematically with known estimates of age at capture, t_c, and time at the start of the growth curve, t_o. Number of recruits can be estimated by determining the yield per recruit for each species and its corresponding *F* level, and then dividing yield per recruit into the catch.

The reporting of commercial landings is voluntary, and there are no legal means of mandating submission of catch reports. Because the commercial catch reports and offshore creel surveys

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[2]An example of estimating mean seasonal catch rates through stratified sampling is shown in Appendix B.

are independent of each other, accuracy of the commercial landing reports cannot be validated. Reported commercial landings were estimated to represent about 40% of the total offshore landings. The worth of commercial landing reports other than monitoring trends in the commercial fishery landings is unknown. The WIDA Project recommends WPACFIN develop a pilot program to authenticate commercial landings.

RECOMMENDATION SUMMARY

In light of recent changes to Guam's small boat fishery the WIDA project recommends (1) seasonal stratified survey sampling to monitor the two other major marine basins, Merizo and Agat, along with Agana Boat Basin, (2) initiate a regimented market sampling program to augment the much-needed biological samples for maturity, age, and growth studies, and (3) initiate a program to monitor the reporting of commercial landings.

ACKNOWLEDGMENTS

Without the help and cooperation from the staff of Guam's Division of Aquatic and Wildlife Resources and WPACFIN this study would not have been possible. Also, sincere thanks to Leslie Williams for her editorial assistance and David Hamm for his invaluable insight to the Guam fishery. Review comments and advice from Dr. Samuel Pooley, Wayne Haight, and Robert Moffitt were greatly appreciated.

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Table 1.--Length-weight regression for fish caught around Guam during 1980-91. Presented for each species are sample size (*N*), fork length (FL) size range of the fitted data, goodness of fit ratio (r^2), and estimates of intercept and slope with their respective standard errors (SE) for the model log(Wt) = a+b'log(FL). Weight is in pounds and fork length in centimeters.

Scientific name	*N*	FL size range(cm)	r^2(%)	Intercept(SE)	Slope(SE)
Caranx sexfaciatus	8	29-65	84	-14.895(2.844)	2.642(0.472)
Caranxlugubris	6	9-56	99	-18.318(0.591)	3.210(0.101)
Caranx melampygus	15	21-85	91	-17.841(1.600)	3.133(0.269)
Caranx ignobilis	5	47-121	96	-24.672(3.178)	4.126(0.488)
Carangoides orthogrammus	16	19-34	97	-16.712(0.772)	2.959(0.136)
Etelis carbunculus	14	26-60	84	-17.289(2.205)	3.027(0.375)
Lethrinus semicinctus	6	27-41	94	-16.768(2.066)	2.982(0.362)
Cephalopholis urodeta	11	13-22	67	-13.356(2.786)	2.313(0.540)
Cephalopholis argus	8	28-40	64	-16.514(5.239)	2.947(0.900)
Sphyraena barracuda	30	60-138	97	-18.895(0.734)	3.116(0.109)
Aphareus furca	5	22-30	80	- 8.585(2.347)	1.472(0.425)
Aprion virescens	13	32-80	71	-13.033(2.889)	2.332(0.454)
Seriola dumerili	5	37-86	99	-15.903(0.197)	2.801(0.030)
Lutjanus kasmira	9	20-25	40	-22.141(10.172)	3.956(1.878)
Variola louti	25	24-48	87	-15.789(1.300)	2.774(0.221)
Coryphaena hippurus	228	60-134	94	-18.095(0.344)	3.033(0.051)
E. curuscans	7	55-80	93	-13.312(1.880)	2.404(0.289)
Elagatis bipinnulatus	26	39-88	95	-14.823(0.791)	2.565(0.126)
Xyrichtys pavo	12	25-41	96	-17.709(1.173)	3.126(0.203)
L. rubrioperculatus	38	19-48	79	-15.041(1.303)	2.651(0.230)
Aphareus rutillans	10	23-95	99	-16.561(0.498)	2.884(0.080)
Naso lituratus	7	19-28	94	-15.981(1.805)	2.850(0.330)
Sargorentron spiniferum	16	21-31	84	-15.128(1.771)	2.701(0.320)
Cephalopholis sommerati	11	20-33	99	-18.224(0.689)	3.214(0.120)

Table 1.--Continued.

Scientific name	*N*	FL size range(cm)	r^2(%)	Intercept(SE)	Slope(SE)
Acanthocybium solandri	127	69-140	96	-20.071(0.412)	3.272(0.060)
Pristipoimoides zonatus	12	24-40	93	-17.986(1.561)	3.198(0.274)
P. auricilia	15	21-36	78	-16.242(2.400)	2.870(0.426)
P. flavipinnis	9	27-54	98	-17.752(1.105)	3.106(0.185)
P. filamentosus	8	25-35	58	-12.191(4.268)	2.149(0.748)
Eepinephelus faciatus	34	18-32	72	-12.774(1.339)	2.208(0.241)
Istophorus platypterus	5	108-202	66	-15.897(10.231)	2.648(1.355)
Makaira nigicans	35	108-269	29	- 7.436(3.298)	1.603(0.438)
Katsuwonus pelamis	256	36-79	93	-19.814(0.375)	3.448(0.060)
Euthynnus affinis	8	32-65	99	-20.488(0.691)	3.547(0.114)
Gymnosarda unicolor	14	21-126	92	-14.446(1.306)	2.561(0.206)
Thunnus albacares	144	43-151	97	-17.434(0.302)	3.057(0.046)

Table 2.--Mean condition indexes for fish caught around Guam during 1980-91. Presented for each species are sample size (*N*), mean *K* value, and variance are presented for each species.

Scientific name	*N*	Mean *K* value	Variance
Caranx melampygus	15	1.115	0.073
Carangoides orthogrammus	16	2.296	0.097
Sphyraena barracuda	31	0.364	0.004
Acanthocybium solandri	132	0.162	0.001
Coryphaena hippurus	228	0.680	0.004
Elagatis bipinnulatus	27	6.457	3.502
Gymnosarda unicolor	15	8.885	15.297
Katsuwonus pelamis	256	0.318	0.001
Thunnus albacares	144	1.405	0.046
Xyrichtys pavo	13	1.152	0.110
Lethrinus rubrioperculatus	38	6.132	2.414
Aphareus rutilans	10	2.244	0.064
Epinephelus fasciatus	35	21.446	17.727
Variola louti	26	3.670	0.943
Pristipomoides zonatus	12	1.112	0.022
P. auricilla	15	3.039	0.410
Etelis carbunculus	14	1.551	0.195
Aprion virescens	13	22.343	35.407

Table 3.--Percentage of island wide offshore fishing activity originating from Agana Boat Basin, Guam, in 1980-91 with mean number of daily fishing trips and percent occurrence.

Day type	Percent of fishing activity	Mean daily fishing trips	Percent occurrence
Weekday	≤25	4	3
>	25 and ≤ 50	6	33
>	50 and ≤ 75	9	50
>	75 and ≤100	9	14
Weekend or holiday	≤25	4	1
>	25 and ≤ 50	12	32
>	50 and ≤ 75	17	58
>	75 and ≤100	18	8

Table 4.--Variance-mean regressions of daily fishing trips around Guam during 1980-91. Given for each fishing method and type of day are the degrees of freedom (df) and the estimates of intercept and slope with their respective significance levels for the model log(Var) = a+b'log(Mean).

	Season	df	Intercept	Pr>F	Slope	Pr>F
			Trolling			
Weekday	Winter	10	0.17	0.84	1.42	0.06
	Spring	10	-1.5	0.01	2.40	0.001
	Summer	10	-1.04	0.06	2.15	0.001
	Fall	10	-0.02	0.97	1.44	0.02
Weekend	Winter	10	0.21	0.83	1.35	0.05
	Spring	10	-2.43	0.01	2.79	0.001
	Summer	10	-0.66	0.66	1.78	0.09
	Fall	10	0.06	0.96	1.34	0.09
			Bottomfishing			
Weekday	Winter	10	0.40	0.000	1.35	0.000
	Spring	10	0.44	0.002	1.05	0.000
	Summer	10	0.57	0.002	0.89	0.000
	Fall	10	0.40	0.002	1.15	0.000
Weekend	Winter	9	0.27	0.16	1.57	0.000
	Spring	10	0.37	0.05	1.24	0.000
	Summer	10	0.48	0.37	1.19	0.02
	Fall	10	0.29	0.73	1.29	0.15
			Spearfishing			
Weekday	Winter	7	0.47	0.001	1.32	0.003
	Spring	9	0.47	0.000	1.16	0.001
	Summer	8	0.44	0.001	1.64	0.000
	Fall	6	0.26	0.05	0.69	0.06
Weekend	Winter	6	0.61	0.000	1.67	0.000
	Spring	9	0.18	0.29	1.58	0.002
	Summer	10	0.50	0.002	1.09	0.002
	Fall	10	0.39	0.000	1.10	0.001

Table 5.--Estimated mean and variance of catch rates in Guam during 1989-91 from both random sampling and ratio estimator models for trolling, bottomfishing, and spearfishing methods by season and day type.

Fishing	Season	Day type	Random sampling Mean	Random sampling Var	Ratio estimator Mean	Ratio estimator Var
Trolling	Winter	WD	4.172	10.175	4.157	0.6355
		WE/H	2.523	1.880	2.494	0.1043
	Spring	WD	2.235	1.719	2.430	0.2763
		WE/H	2.196	1.015	2.237	0.0609
	Summer	WD	2.273	1.235	2.263	0.3240
		WE/H	2.118	0.676	2.224	0.0991
	Fall	WD	1.506	1.137	1.638	0.1229
		WE/H	1.648	0.345	1.592	0.0372
Bottom-fishing	Winter	WD	1.560	3.710	4.423	0.8301
		WE/H	1.499	0.791	1.360	0.1179
	Spring	WD	1.642	2.579	1.555	0.4958
		WE/H	1.501	0.721	1.419	0.0501
	Summer	WD	2.089	2.297	1.837	0.2841
		WE/H	1.840	1.106	2.114	0.2086
	Fall	WD	2.222	3.341	2.570	0.7913
		WE/H	1.438	0.421	1.261	0.0427
Spear-fishing	Winter	WD	1.392	0.162	1.322	0.0784
		WE/H	3.212	4.550	3.779	2.4672
	Spring	WD	17.601	37.038	17.281	34.1389
		WE/H	6.143	94.456	5.022	3.1566
	Summer	WD	4.703	21.597	4.734	3.9970
		WE/H	6.546	27.496	6.076	10.0334
	Fall	WD	3.694	2.542	3.976	3.6105
		WE/H	3.481	12.845	4.132	2.5331

Table 6.--Estimated number of survey days required to predict trolling trips with 20% precision by season and type of day based on mean number of daily trolling trips around Guam during 1989-91 with both random and negative binomial models.

Season	Day type	No. mean trips	No. survey days (random)	No. survey days (neg. binomial)
Winter	WD	23.49	7	7
	WE/H	59.10	3	5
Spring	WD	23.51	4	4
	WE/H	54.54	2	4
Summer	WD	22.41	3	15
	WE/H	53.45	2	5
Fall	WD	19.30	5	3
	WE/H	53.37	9	1

Table 7.--Estimated number of survey days to estimate 1989-91 mean catch rates in Guam from random sampling and ratio estimator models by trolling, bottomfishing and spearfishing methods and season and day type.

Fishing method	Season	Type of day (No.)	Random sampling (No.)	Ratio estimator (No.)
Trolling	Winter	WD	6	1
		WE/H	9	1
	Spring	WD	13	3
		WE/H	8	2
	Summer	WD	14	4
		WE/H	9	2
	Fall	WD	16	6
		WE/H	6	3
Bottom-fishing	Winter	WD	21	2
		WE/H	19	17
	Spring	WD	20	12
		WE/H	14	10
	Summer	WD	10	7
		WE/H	12	9
	Fall	WD	13	3
		WE/H	20	58
Spear-fishing	Winter	WD	24	2
		WE/H	11	11
	Spring	WD	6	2
		WE/H	14	10
	Summer	WD	9	2
		WE/H	10	9
	Fall	WD	13	5
		WE/H	11	16

Table 8.--Estimated number of survey days required to predict the five major trolling caught species; mahimahi, ono, skipjack and yellowfin tuna, and Pacific blue marlin with 20% precision by season based on mean daily specific catch rates around Guam in 1989-91.

Species	Season	Mean catch rate (kg/gear-h)	Survey days (No.)
Mahimahi	Winter	1.84	22
	Spring	0.76	30
	Summer	0.24	56
	Fall	0.28	41
Ono	Winter	0.73	26
	Spring	0.29	35
	Summer	0.19	47
	Fall	0.73	26
Skipjack	Winter	0.42	72
	Spring	1.26	28
	Summer	0.69	18
	Fall	0.56	44
Yellowfin	Winter	0.37	40
	Spring	1.01	22
	Summer	0.53	17
	Fall	0.15	43
Blue Marlin	Winter	0.90	210
	Spring	0.79	32
	Summer	2.31	39
	Fall	0.32	30

Table 9.--Estimated number of survey days required to predict bottomfishing trips with 20% precision by season and type of day based on mean number of daily bottomfishing trips around Guam during 1989-91 with random and negative binomial models.

Season	Day type	No. mean trips	No. survey days (random)	No. survey days (neg. binomial)
Winter	WD	7.41	5	5
	WE/H	11.90	7	29
Spring	WD	5.39	7	21
	WE/H	13.76	7	16
Summer	WD	6.72	4	6
	WE/H	16.40	7	21
Fall	WD	3.56	7	14
	WE/H	12.89	7	17

Table 10.--Estimated number of survey days required to predict spearfishing trips with 20% precision by season and type of day based on mean number of daily spearfishing trips around Guam during 1989-91 with both random and negative binomial models.

Season	Day type	No. mean trips	No. survey days (random)	No. survey days (neg. binomial)
Winter	WD	2.55	5	42
	WE/H	4.37	7	11
Spring	WD	3.29	5	17
	WE/H	3.49	6	57
Summer	WD	5.12	2	10
	WE/H	4.29	3	28
Fall	WD	2.63	6	15
	WE/H	2.31	6	22

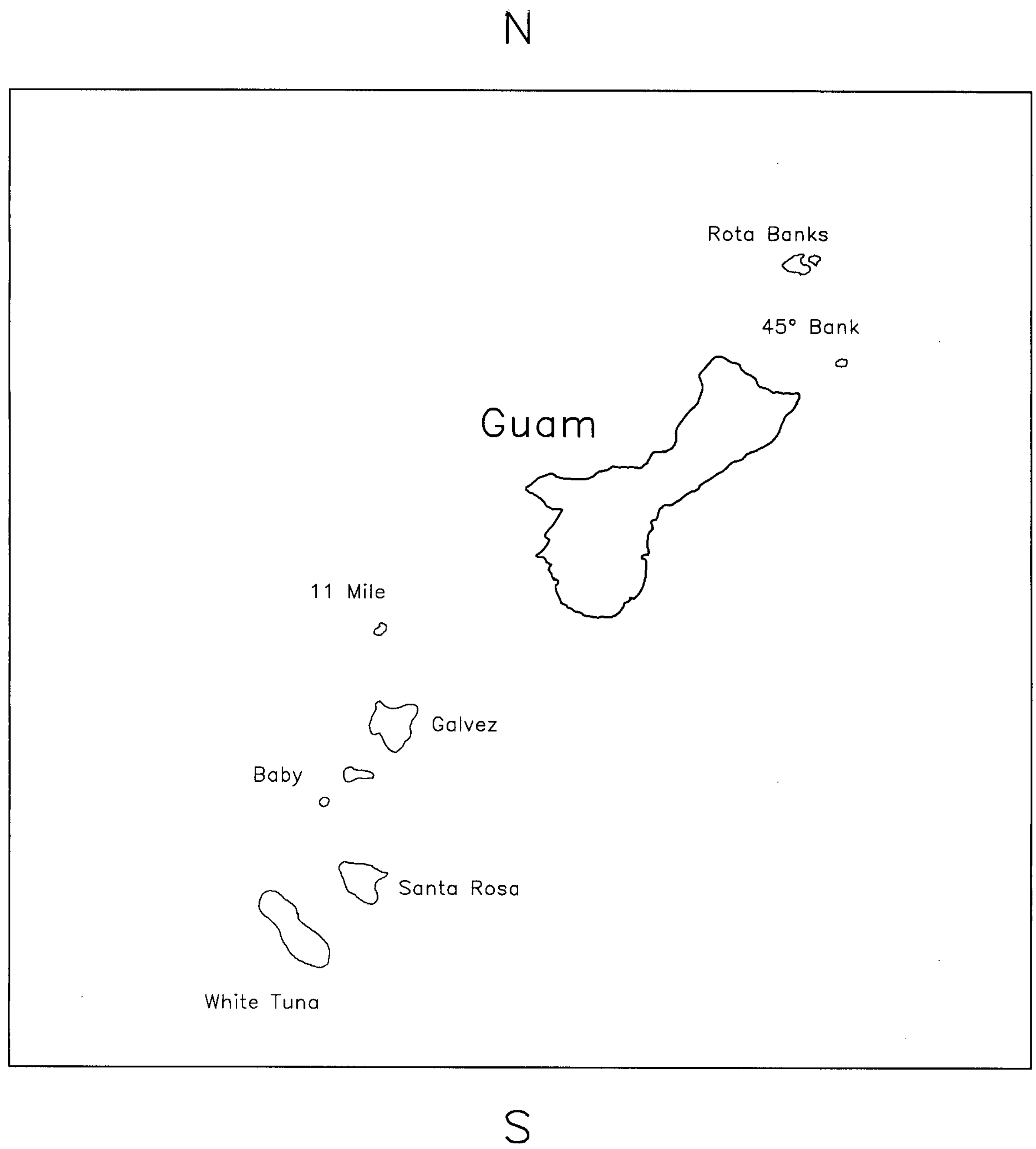

Figure 1.--Map of Guam and the surrounding offshore banks.

Division of Aquatic & Wildlife Resources
Department of Agriculture
Government of Guam

Offshore Creel Census

Date ____________ 1 WD/ 2 WE

Landing ____________

Interview # ________
Interviewer ________
Interview time ________

Method

Method	Gear units	hrs.in use	Area fished
1. Trolling			
2. Bottomfish sh/dp			
3. Atulai nightlight			
5. Spear/snorkel			
6. Spear/SCUBA			
_. Other (specify)			

No. of people on board ______
Charter? yes/no No. guests ___

Weather ___ Cloud cover ___
Wind direction ____ speed ___
Lunar day ___ Typhoon cond. ___
Warnings: Sm craft ___ High Sf ___
(check if yes; ? if unknown)

FAD Data
(fill in if fished near a FAD)
Start time ___ Hrs fished ___
No. passes ___

Species	No.	Weigh

Boat # ____________ berthed? yes no Towing vehicle lic. # ____________

					Type data:		1	3	1	2	3
	Length	Wt.	Length	Wt.	Length	Wt.	Total Number		Total Weight		
SPECIES/Code	(mm)	(Kg.)	(mm)	(Kg.)	(mm)	(Kg.)	Act.	Est.	Act.	Calc.	Est.

Catch Disposition

		remarks		remarks
Method				
% kept				
% sold to co-op				
% sold elsewhere				

Catch Summary	1 act.	2 calc.	3 est.
Method ______			
Total no. fish			
Total wt. (kg)			
Total no. species			
Method ______			
Total no. fish			
Total wt. (kg)			
Total no. species			

Figure 2.--Guam Division of Aquatic and Wildlife Resources offshore creel census form for recording individual boat fishing activity.

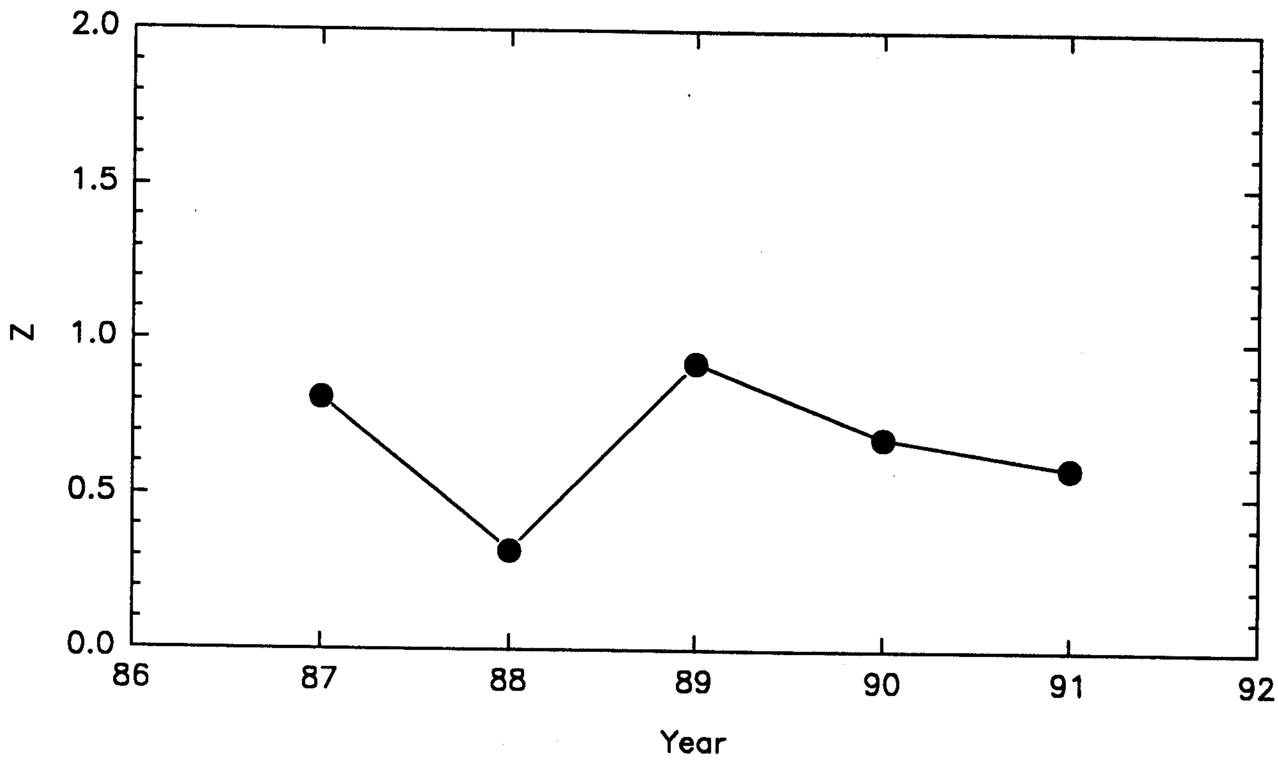

Figure 3.--Annual estimates of total mortality (*Z*) from 1987-91 for the red-gilled emperor, *Lethrinus rubrioperculatus*, caught around Guam.

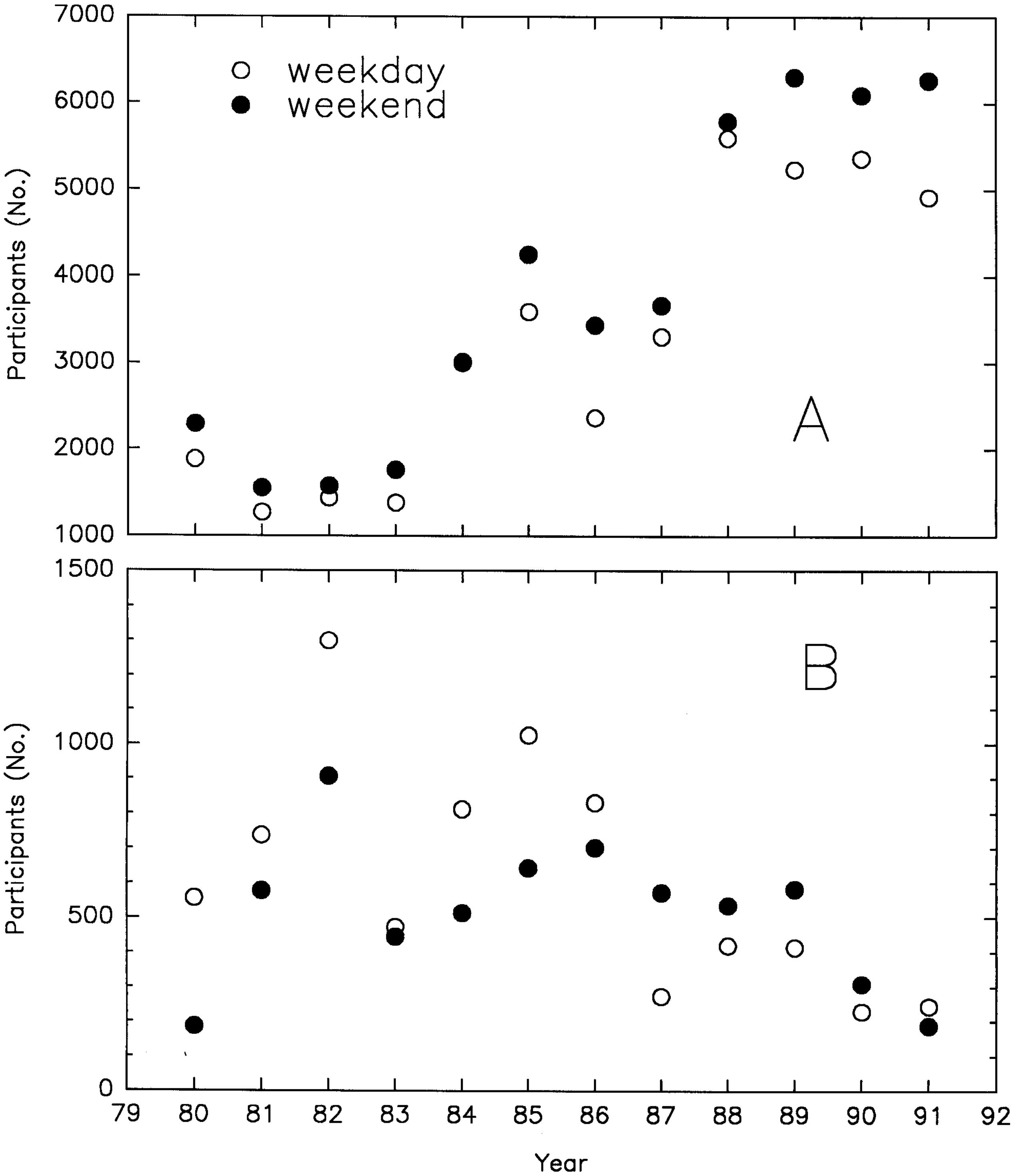

Figure 4.--Estimated number of annual trolling trips around Guam from 1980-91 to nearshore areas (A) and distant offshore banks (B) for both weekdays and weekends or holidays.

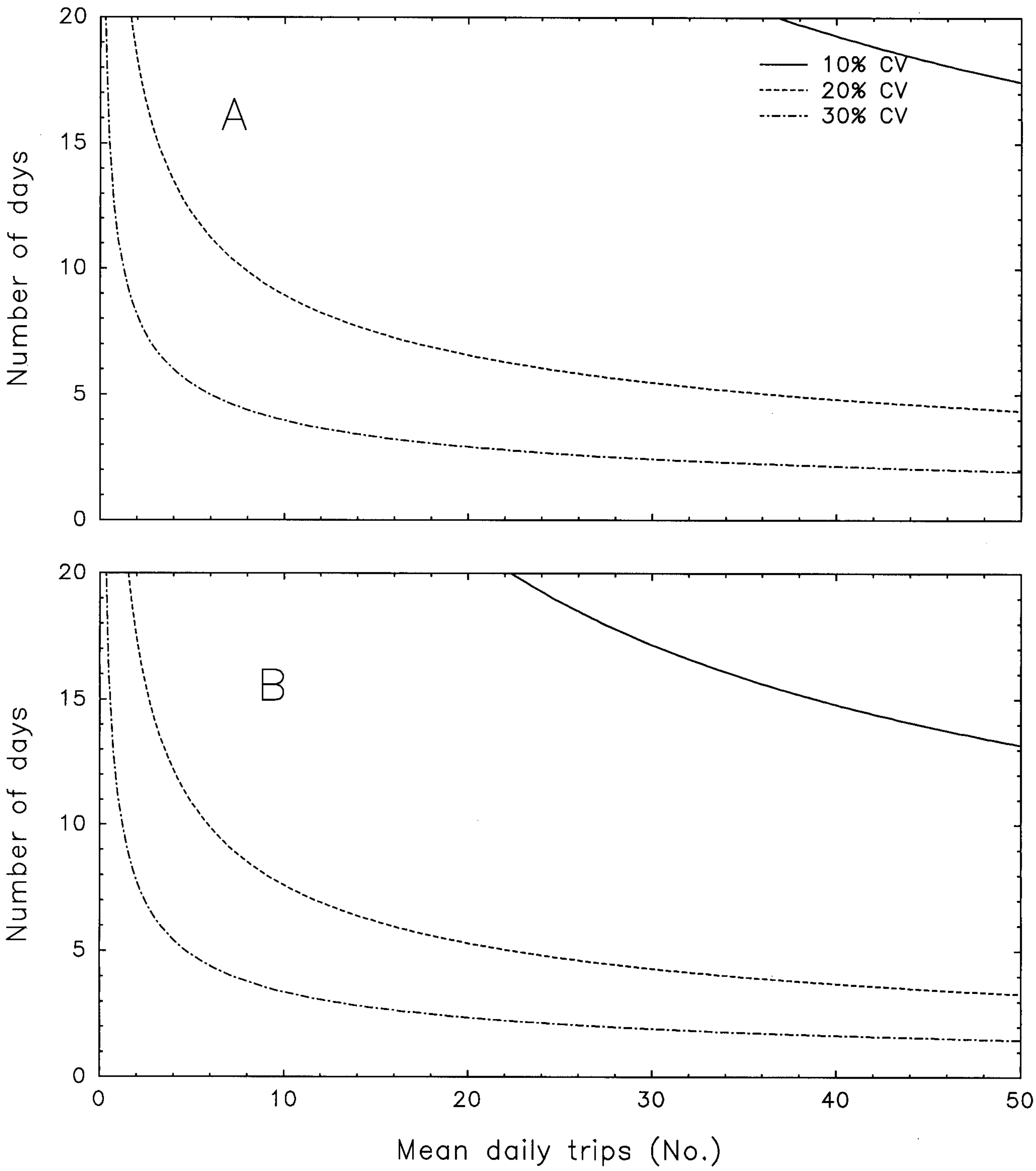

Figure 5.--Required sample size for estimating mean winter trolling activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

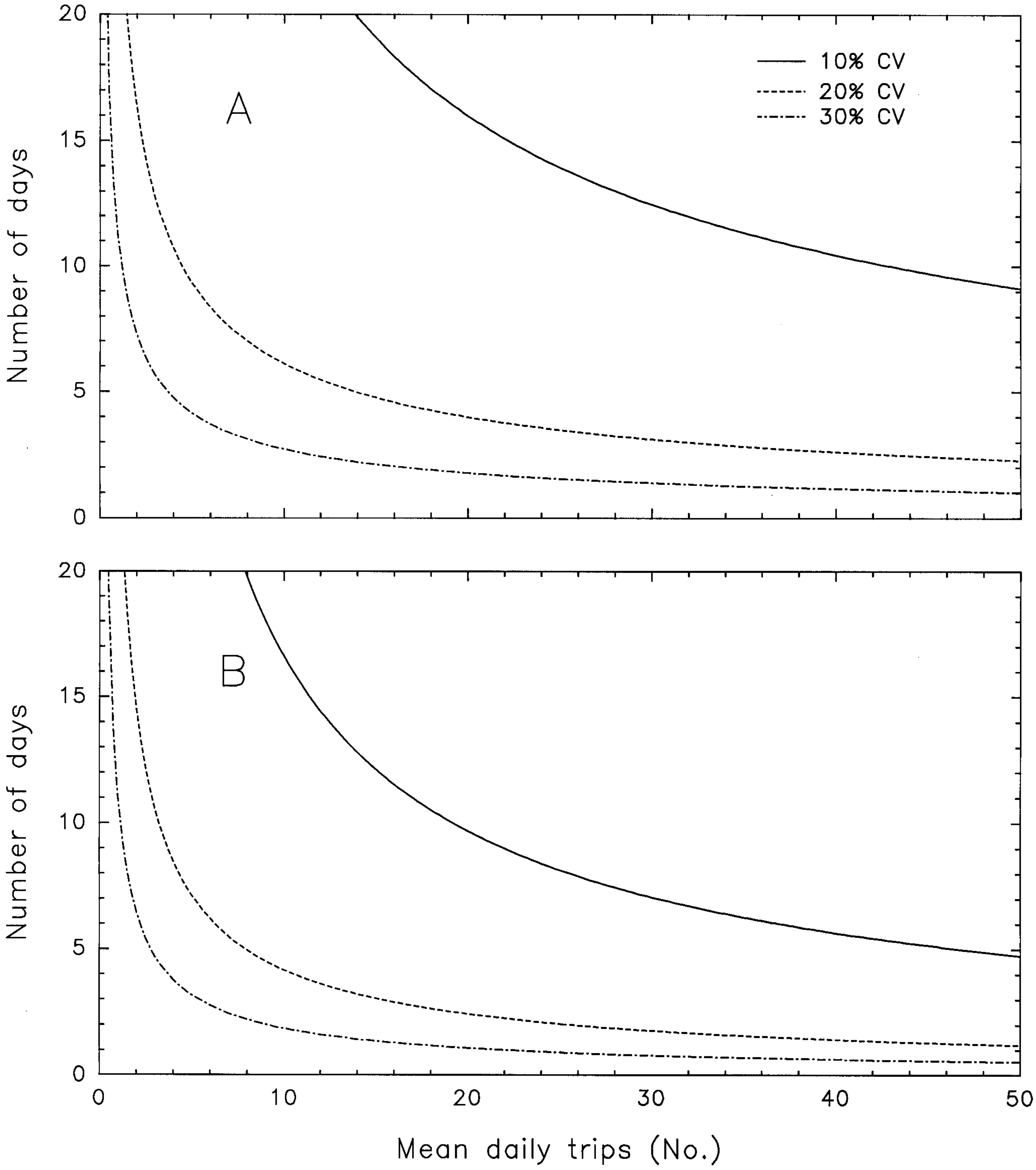

Figure 6.--Required sample size for estimating mean spring trolling activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

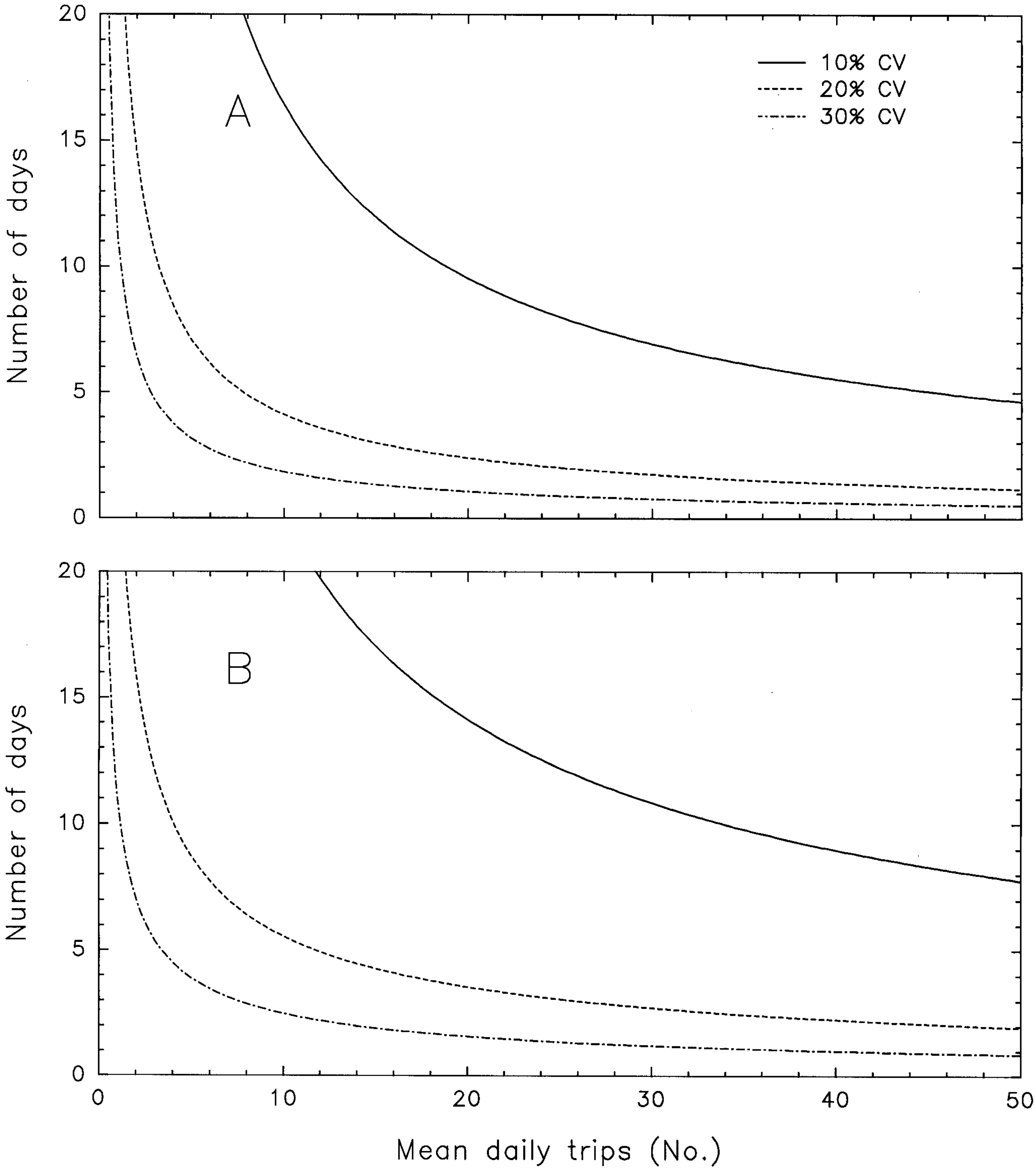

Figure 7.--Required sample size for estimating mean summer trolling activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

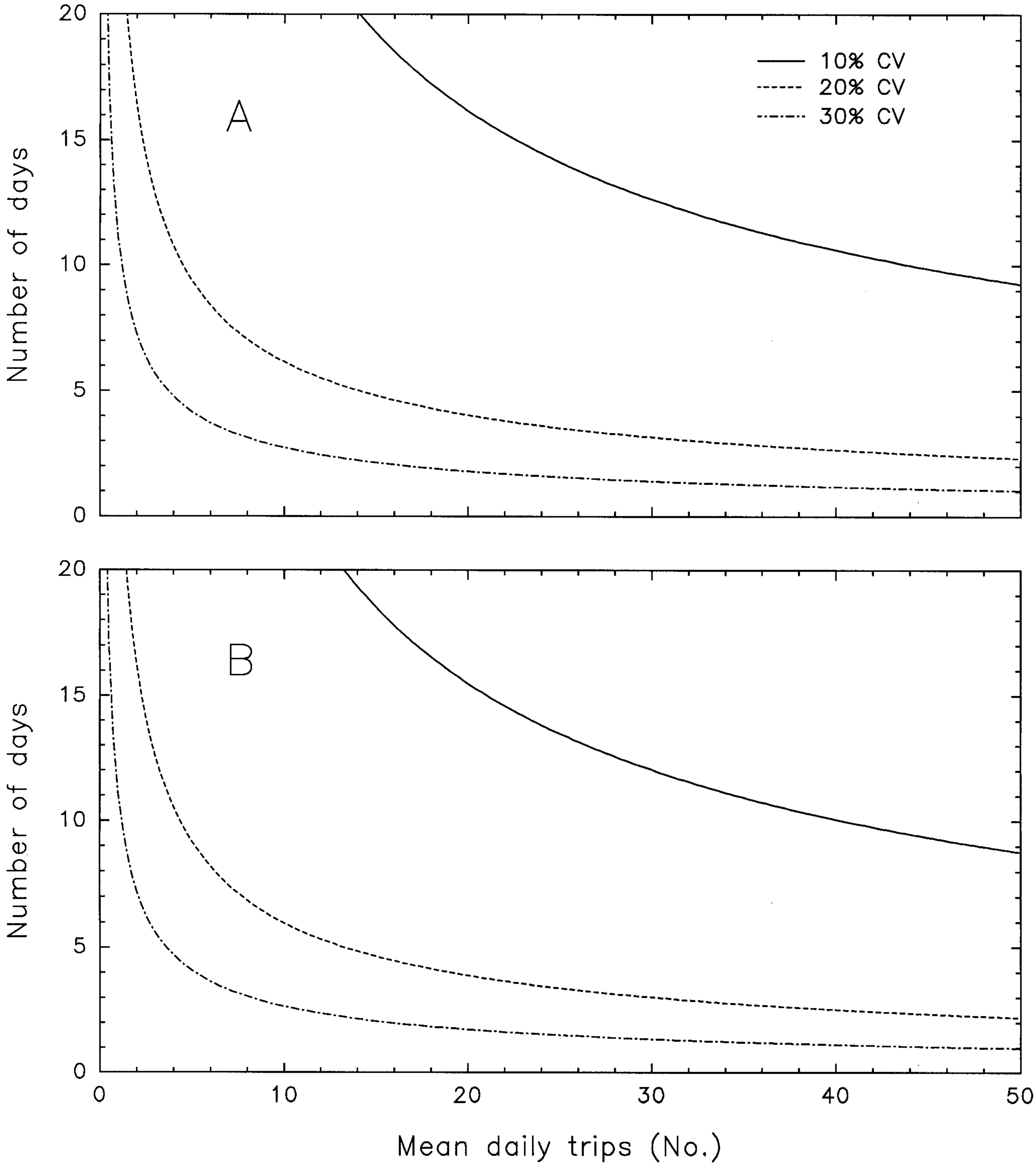

Figure 8.--Required sample size for estimating mean fall trolling activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

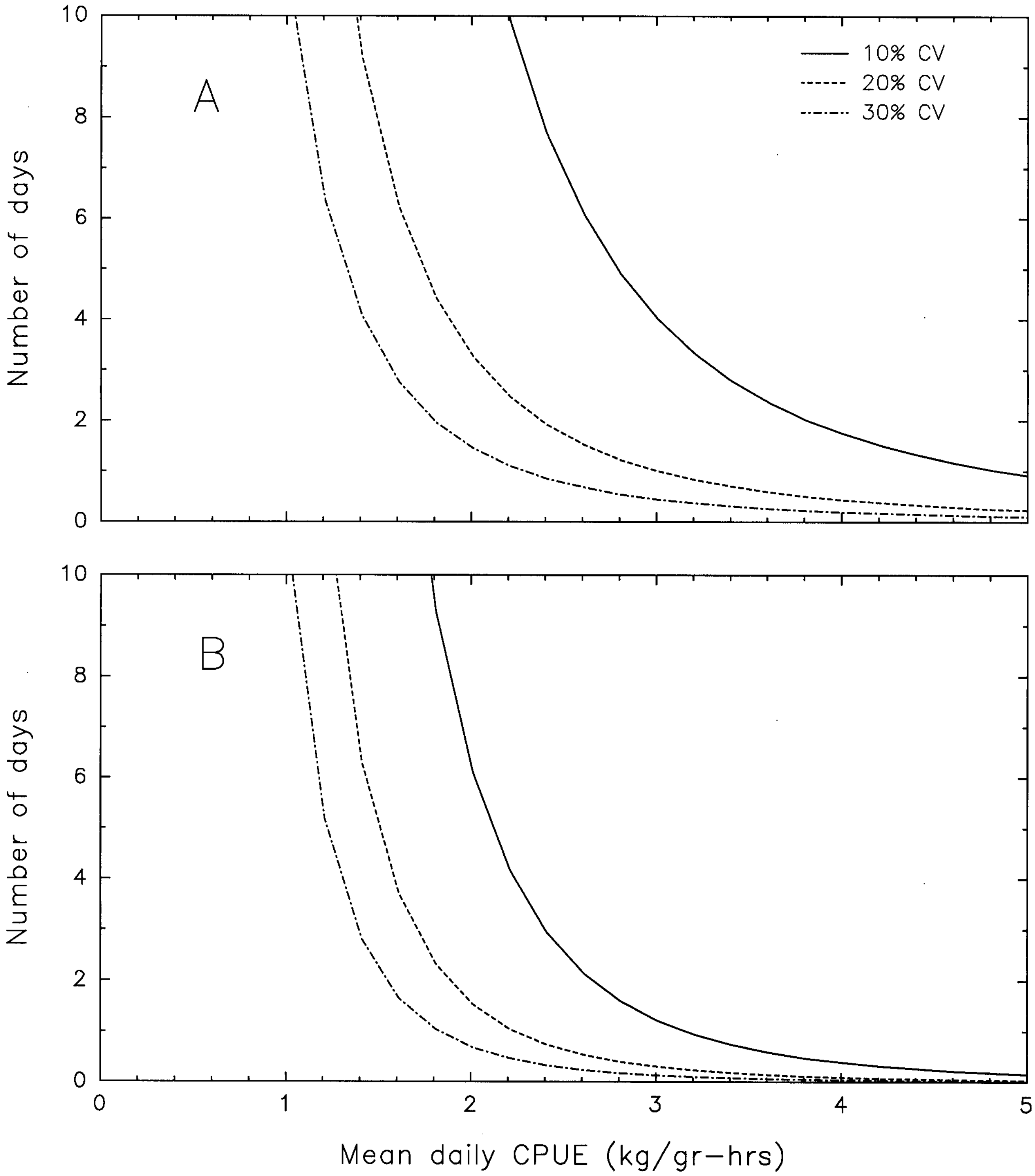

Figure 9.--Required sample size for estimating mean winter trolling CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

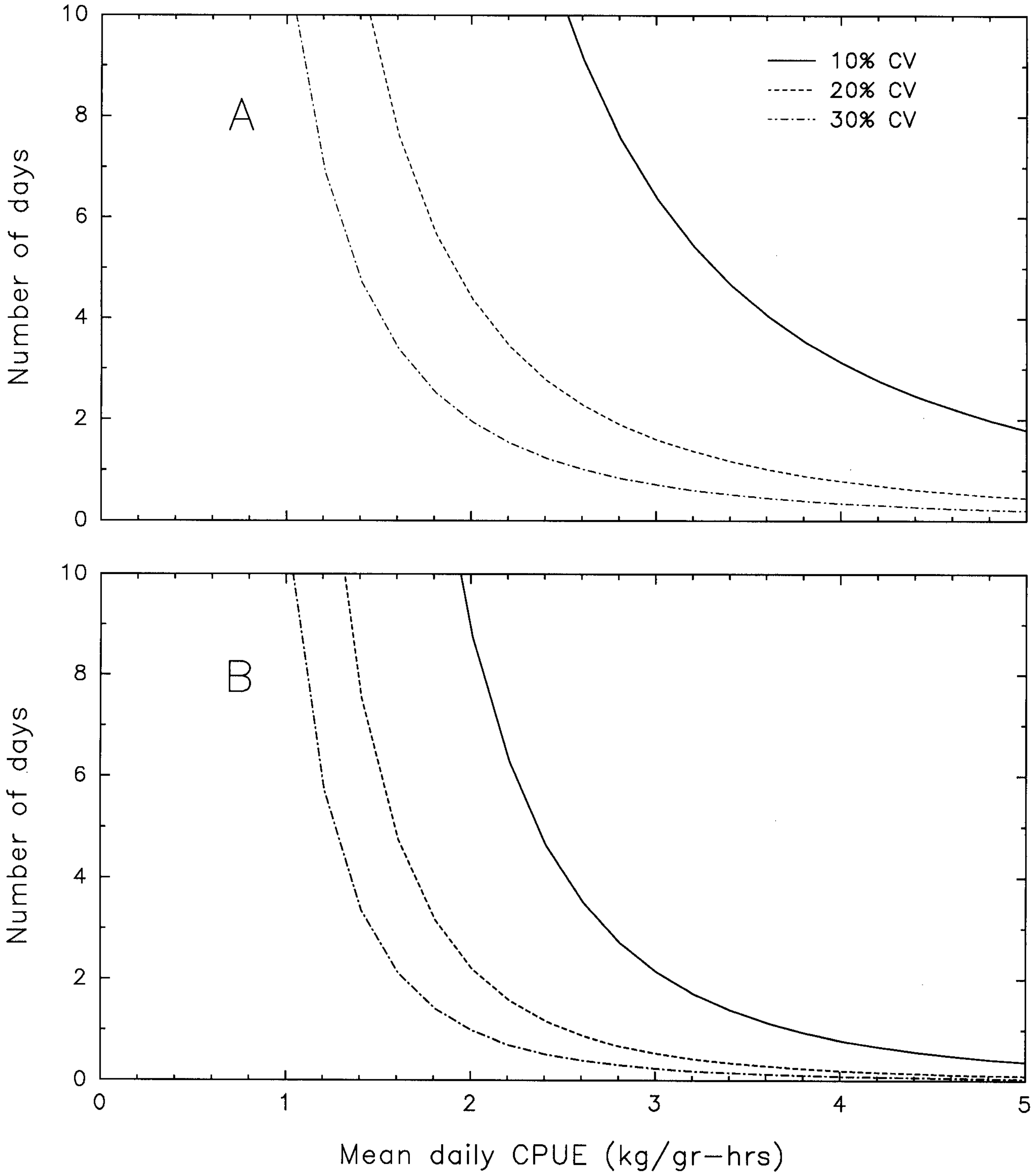

Figure 10.--Required sample size for estimating mean spring trolling CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

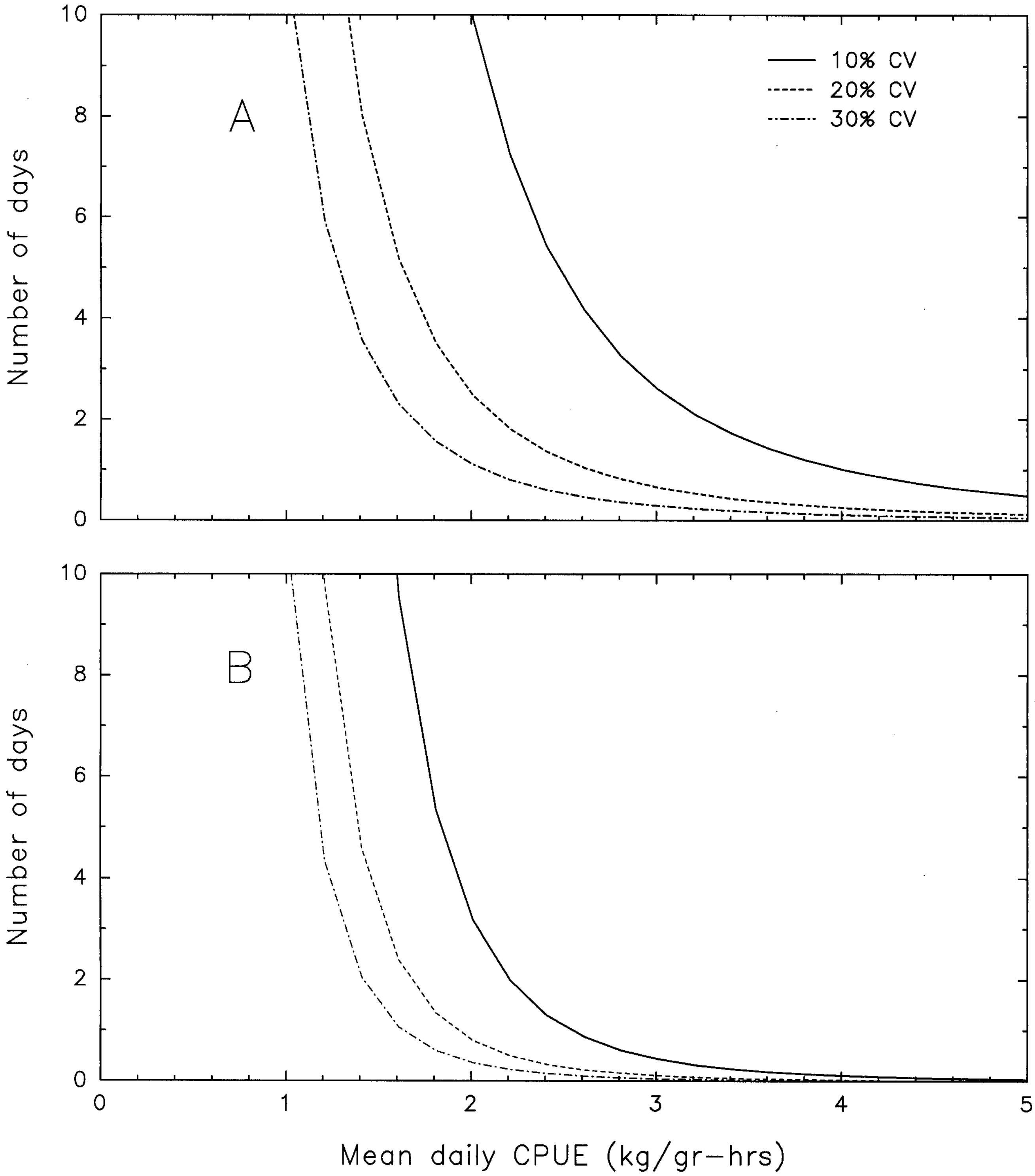

Figure 12.--Required sample size for estimating mean fall trolling CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

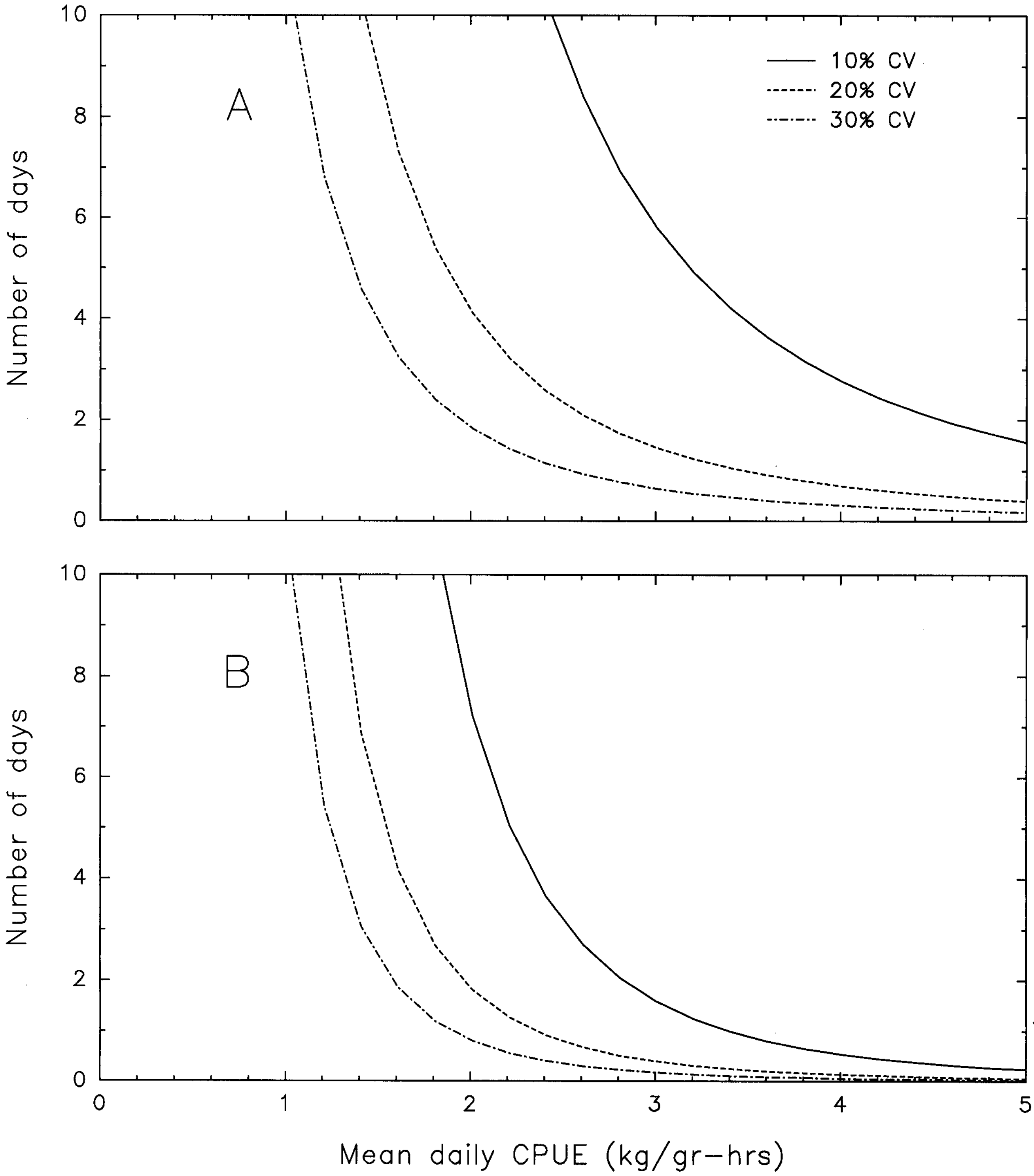

Figure 11.--Required sample size for estimating mean summer trolling CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

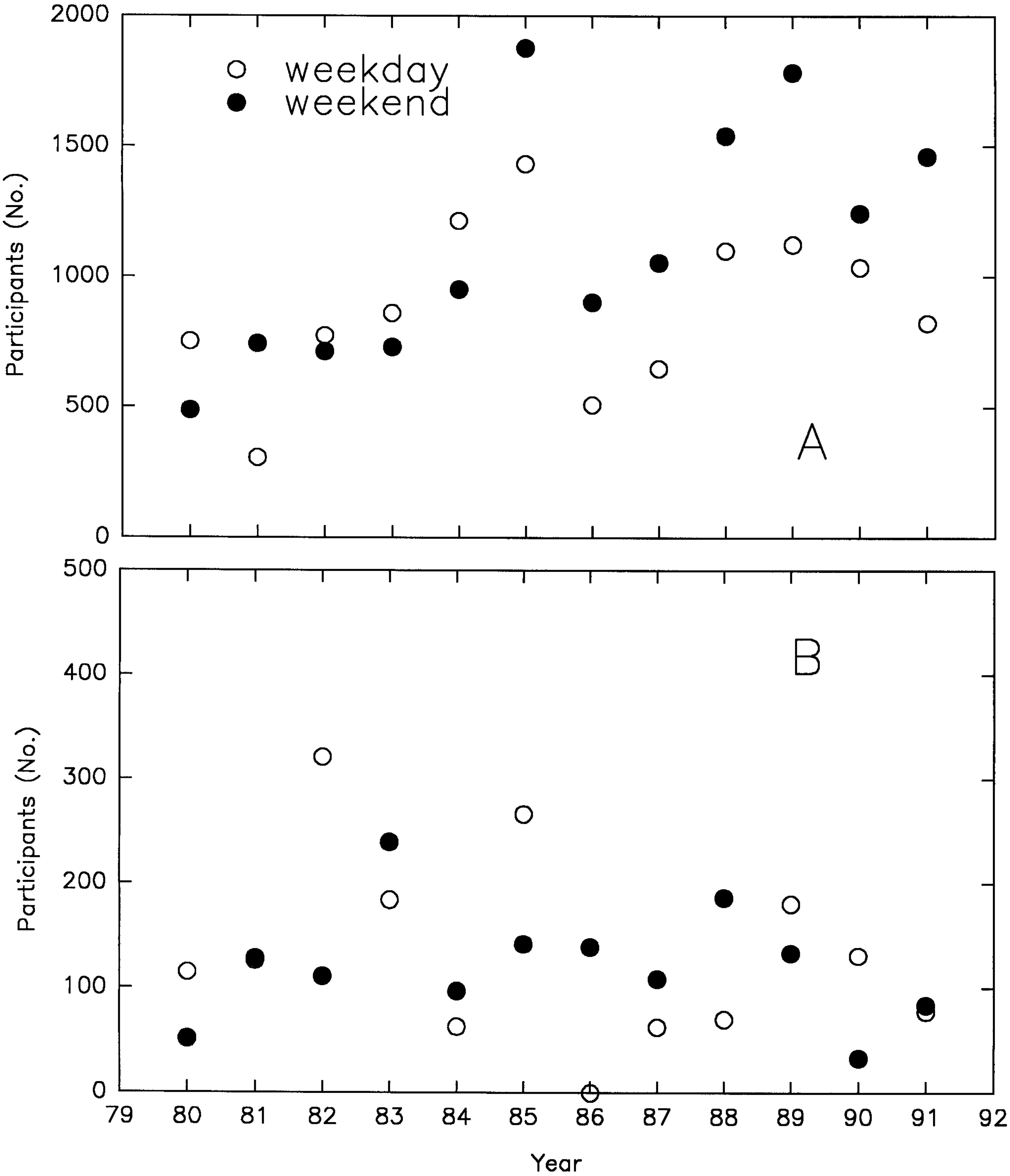

Figure 13.--Estimated number of annual bottomfishing trips around Guam from 1980-91 to nearshore areas (A) and distant offshore banks (B) for both weekdays and weekends or holidays.

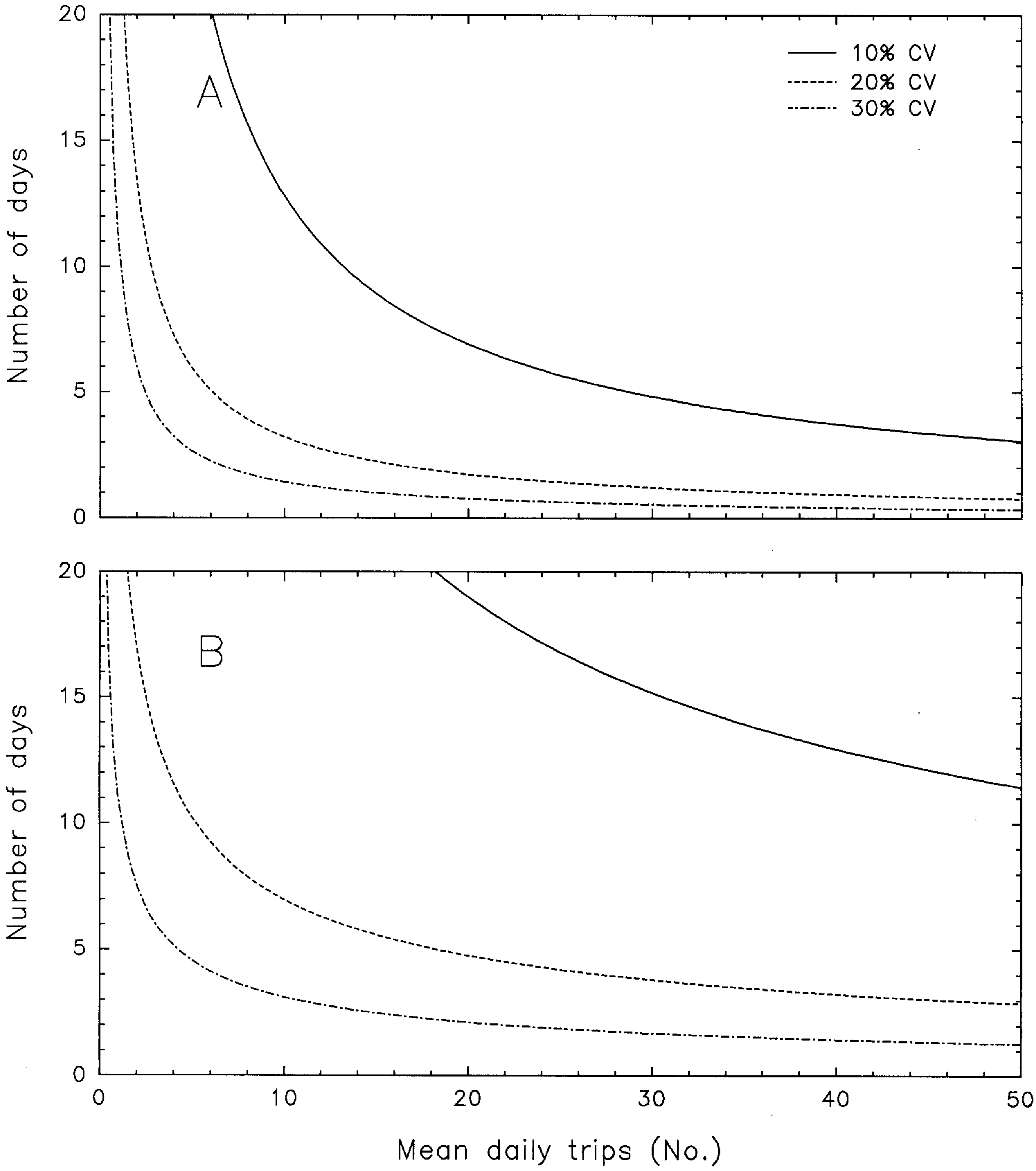

Figure 14.--Required sample size for estimating mean winter bottomfishing activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

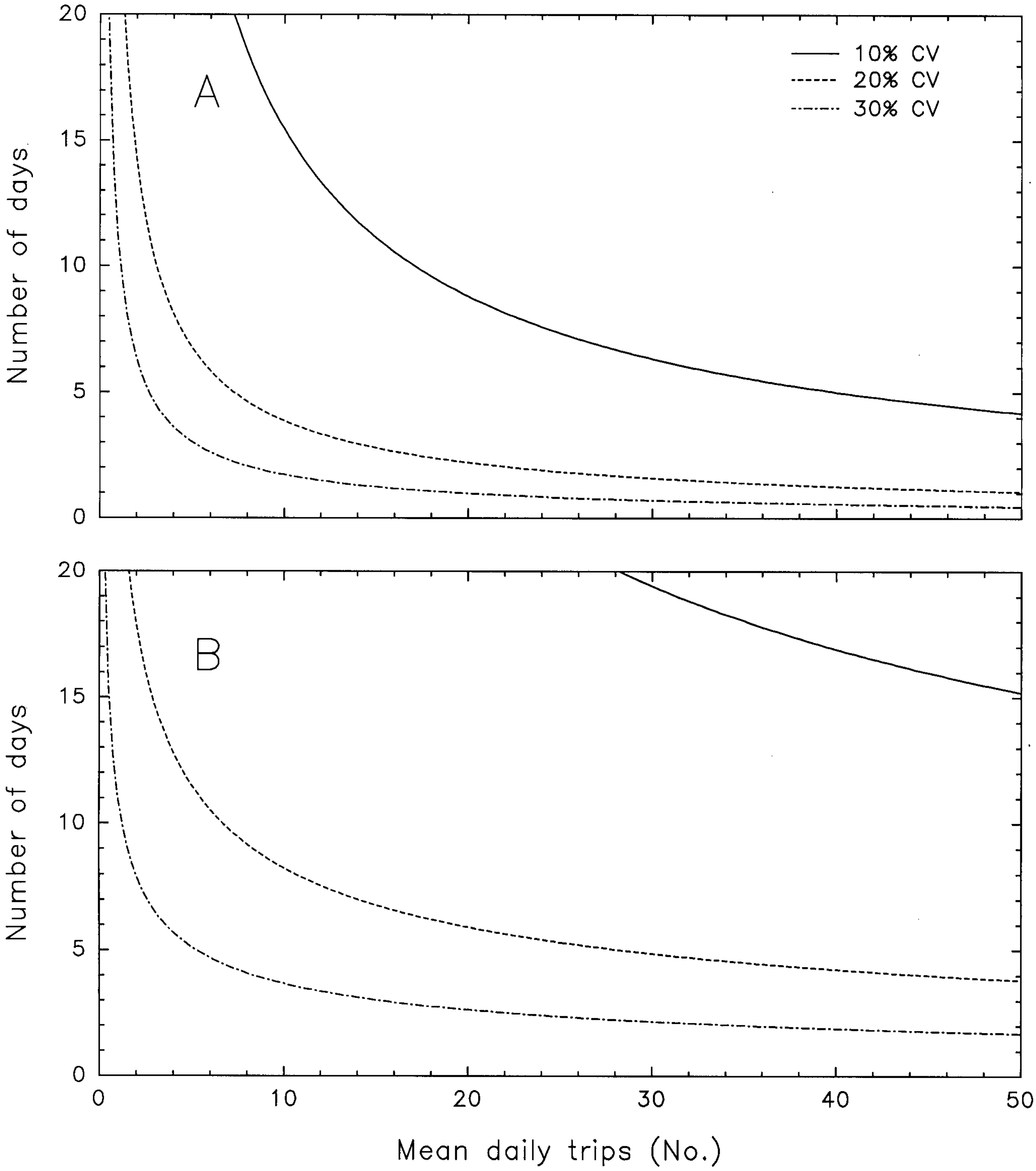

Figure 15.--Required sample size for estimating mean spring bottomfishing activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

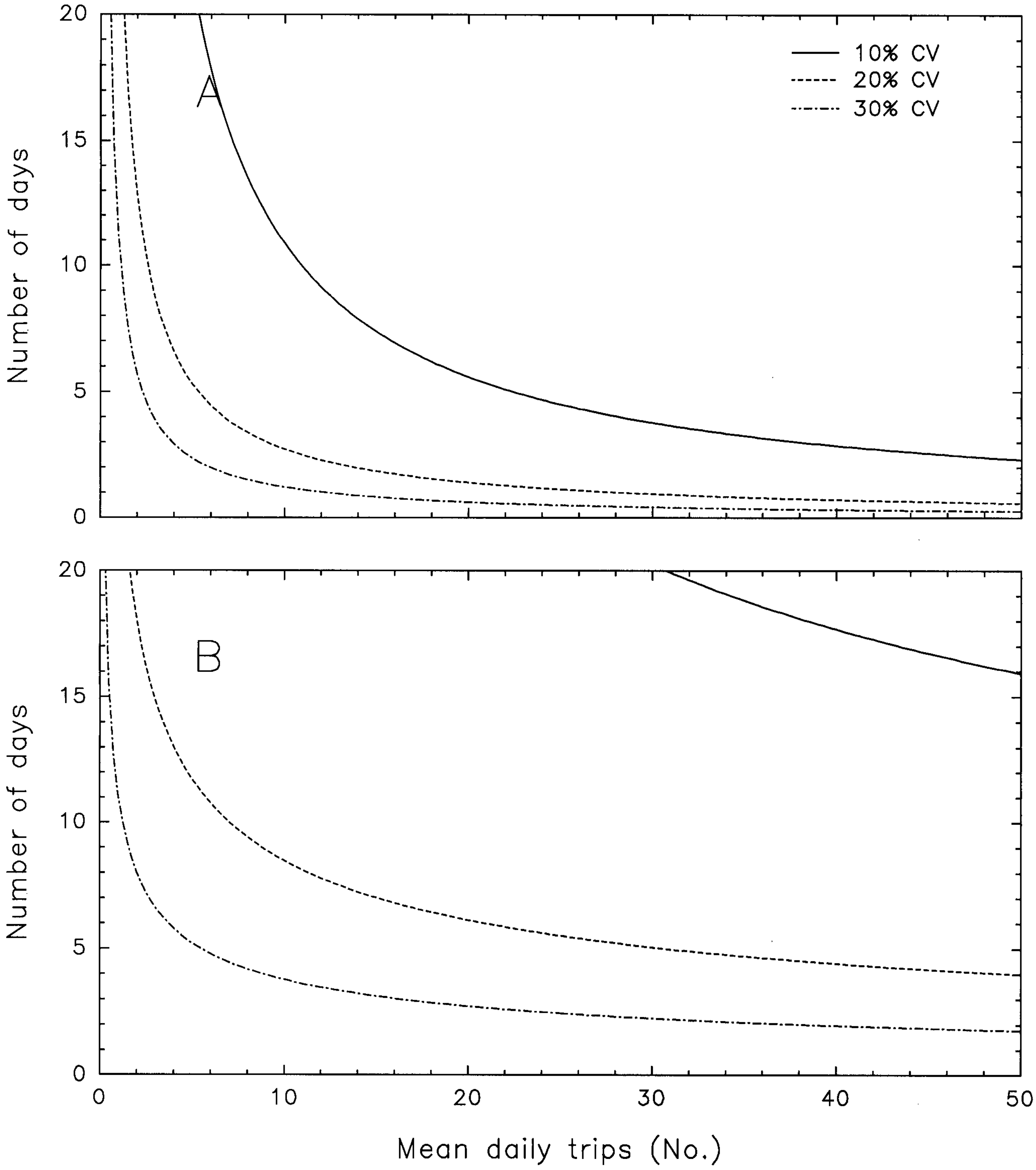

Figure 16.--Required sample size for estimating mean summer bottomfishing activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

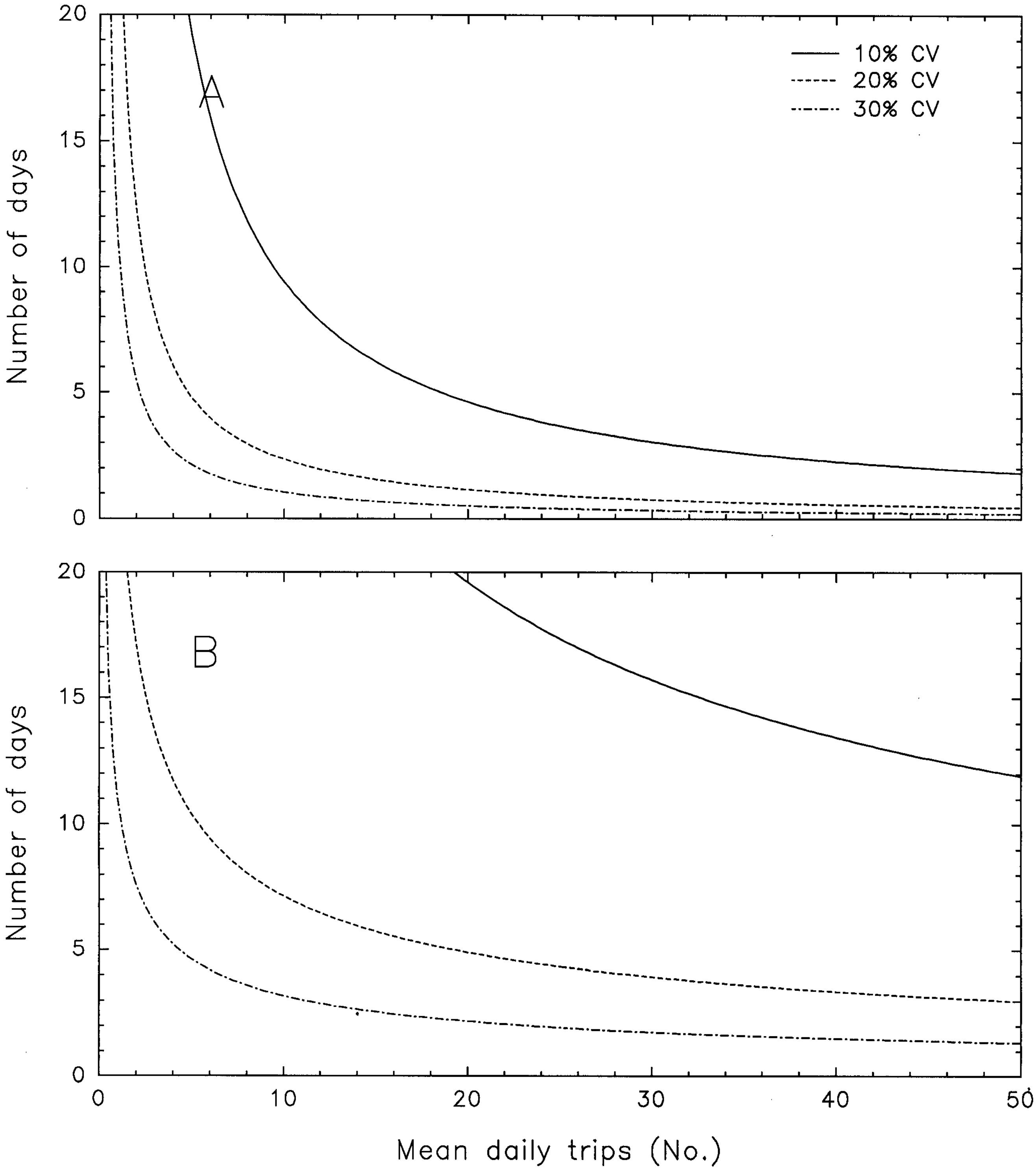

Figure 17.--Required sample size for estimating mean fall bottomfishing activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

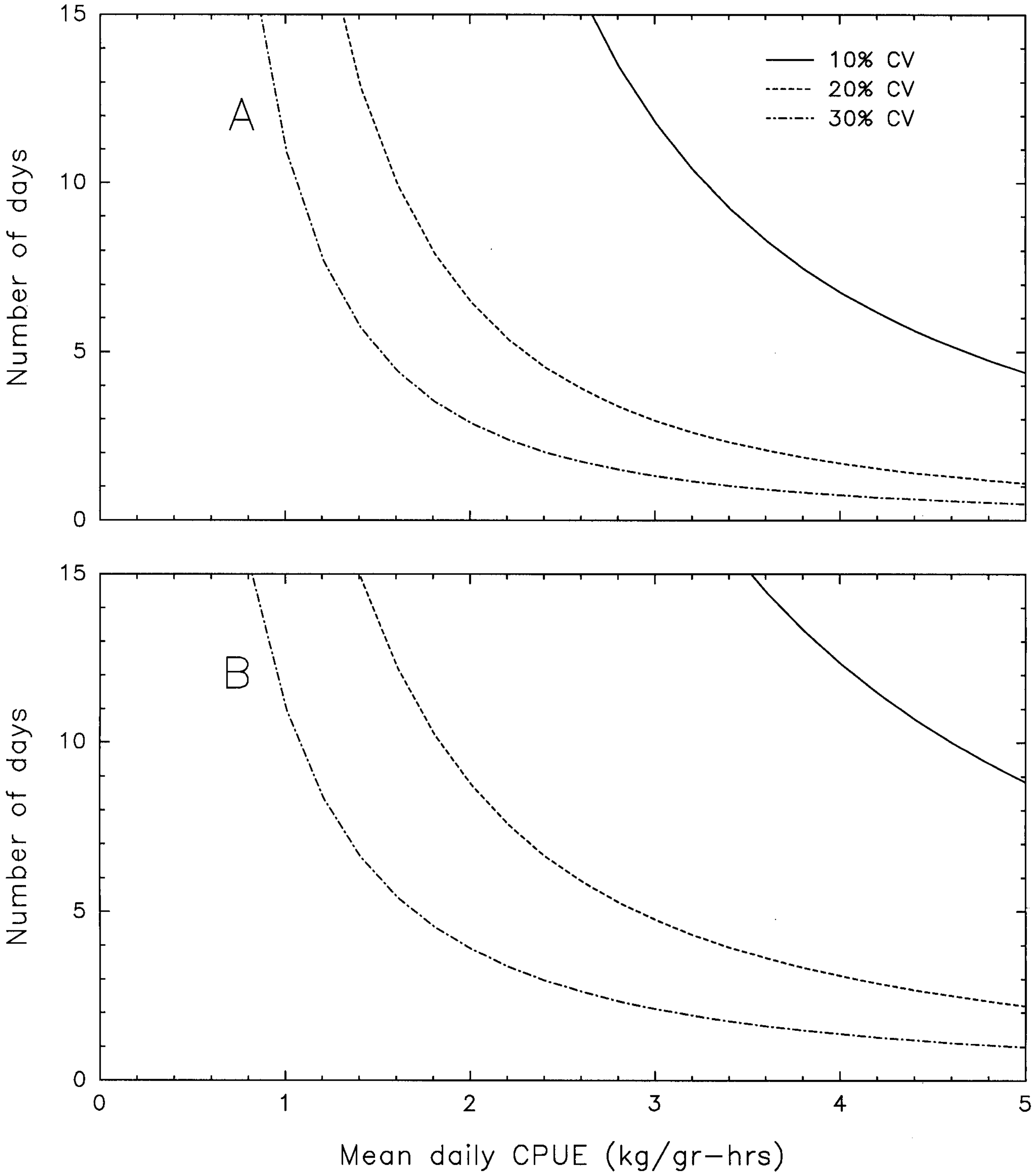

Figure 18.--Required sample size for estimating mean winter bottomfishing CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

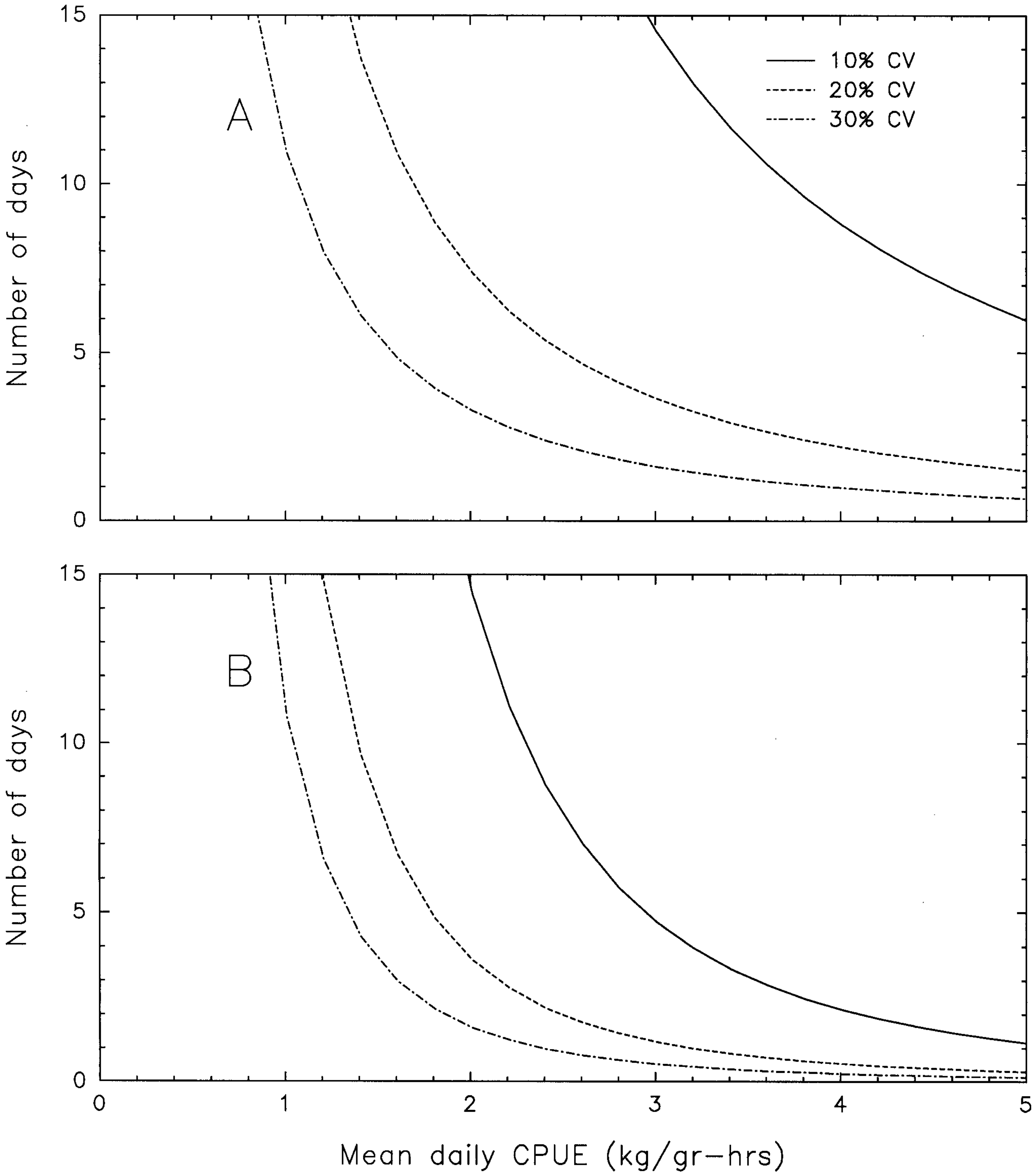

Figure 19.--Required sample size for estimating mean spring bottomfishing CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

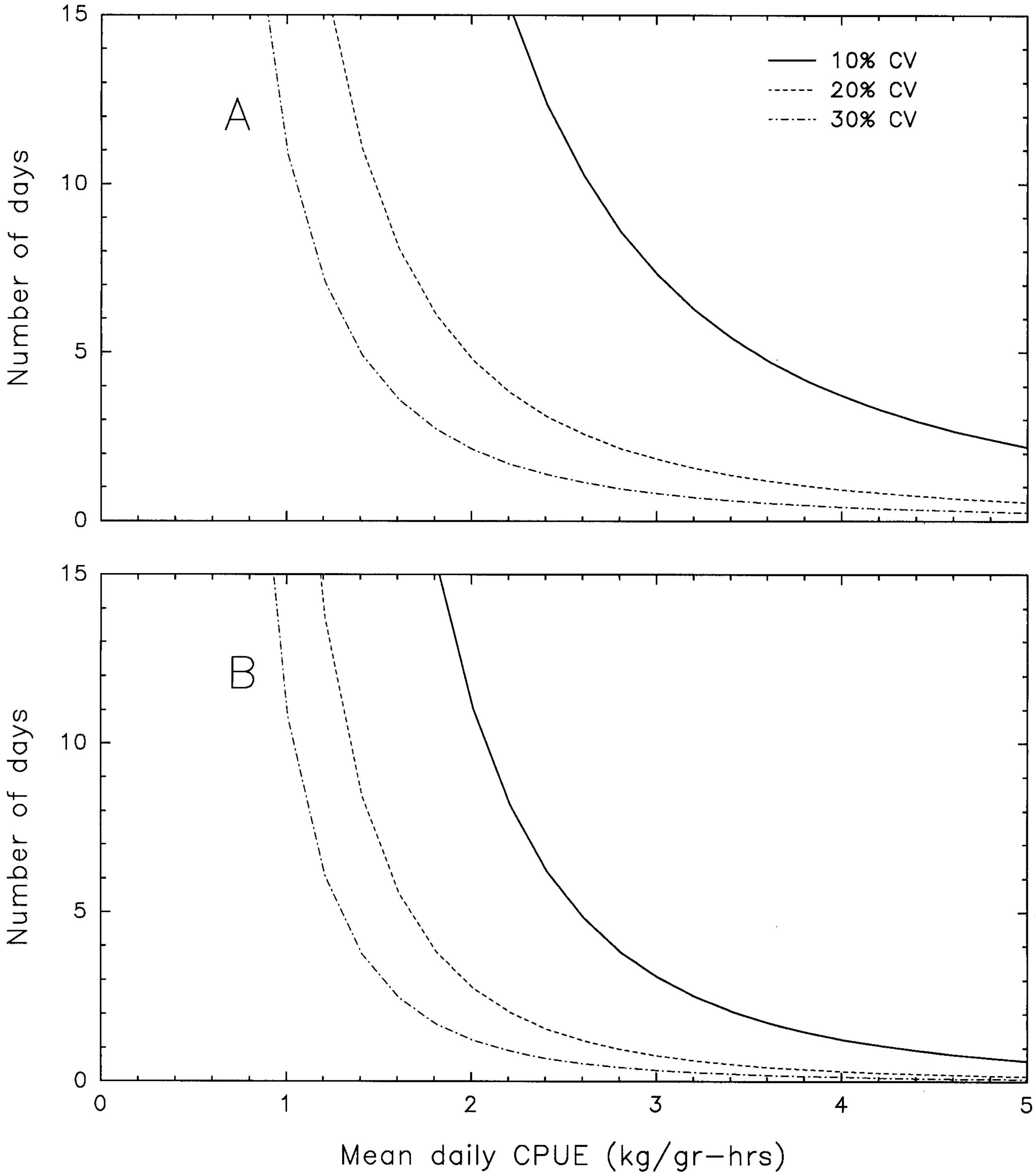

Figure 20.--Required sample size for estimating mean summer bottomfishing CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

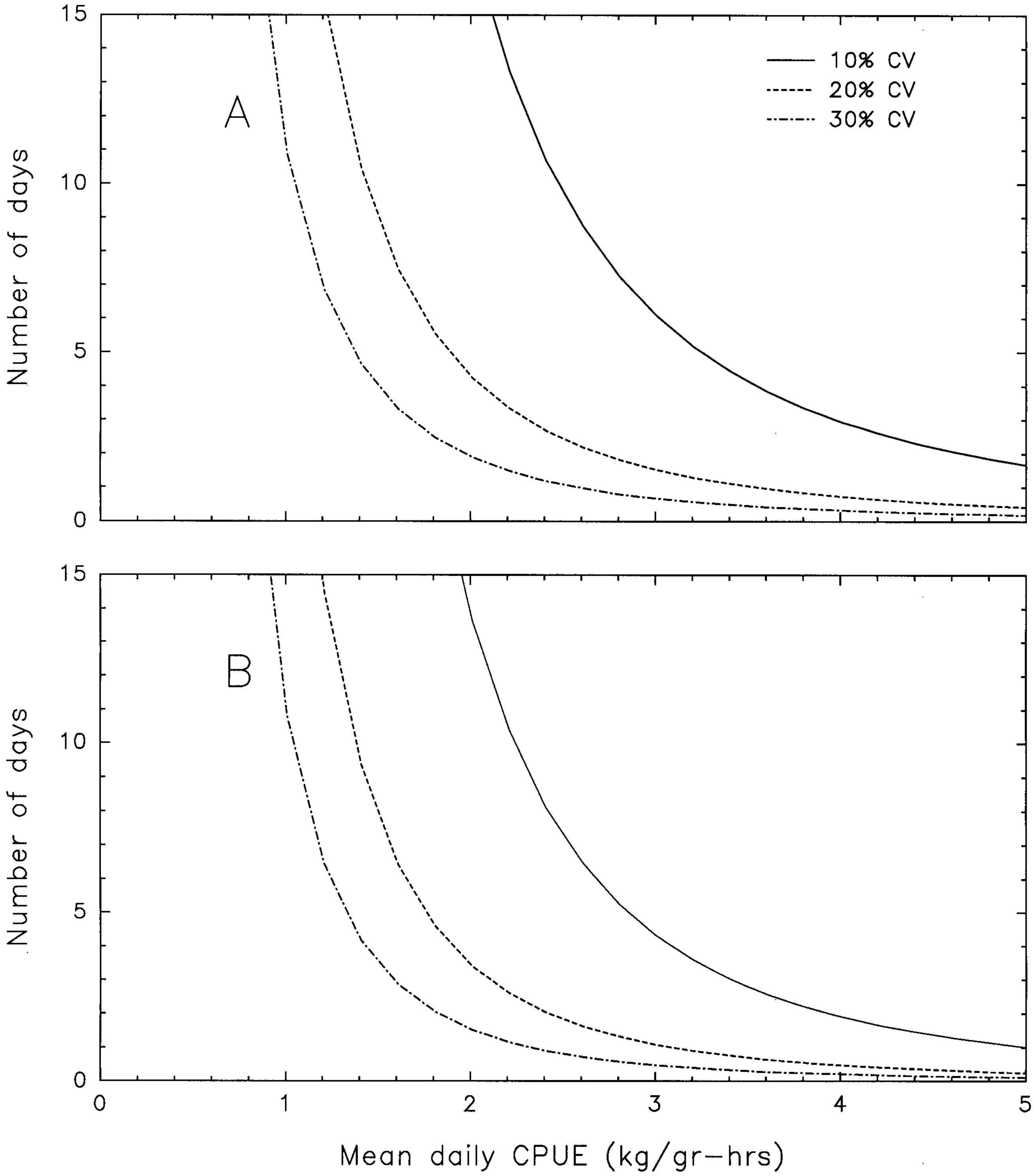

Figure 21.--Required sample size for estimating mean fall bottomfishing CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

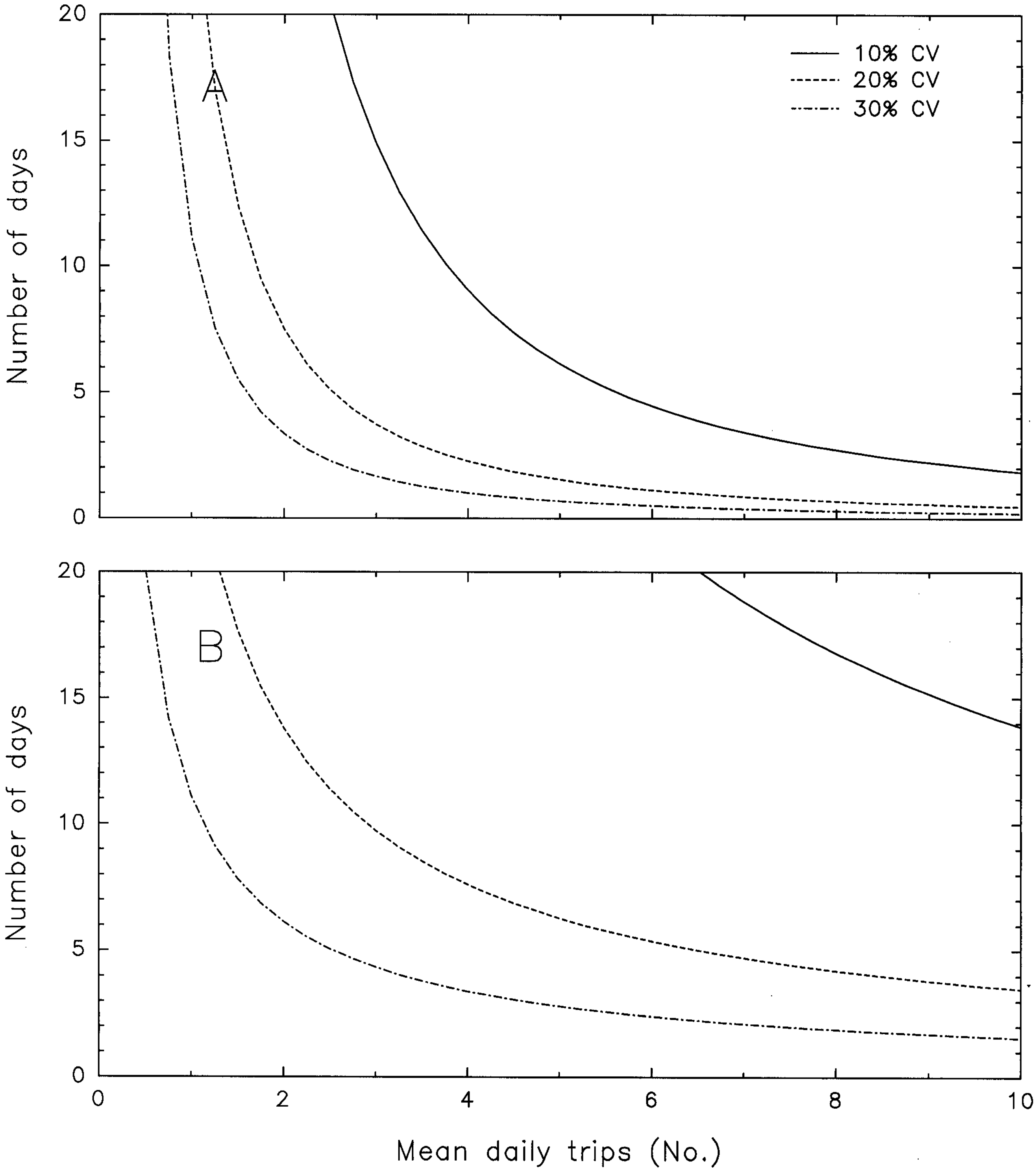

Figure 22.--Required sample size for estimating mean winter spearfishing activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

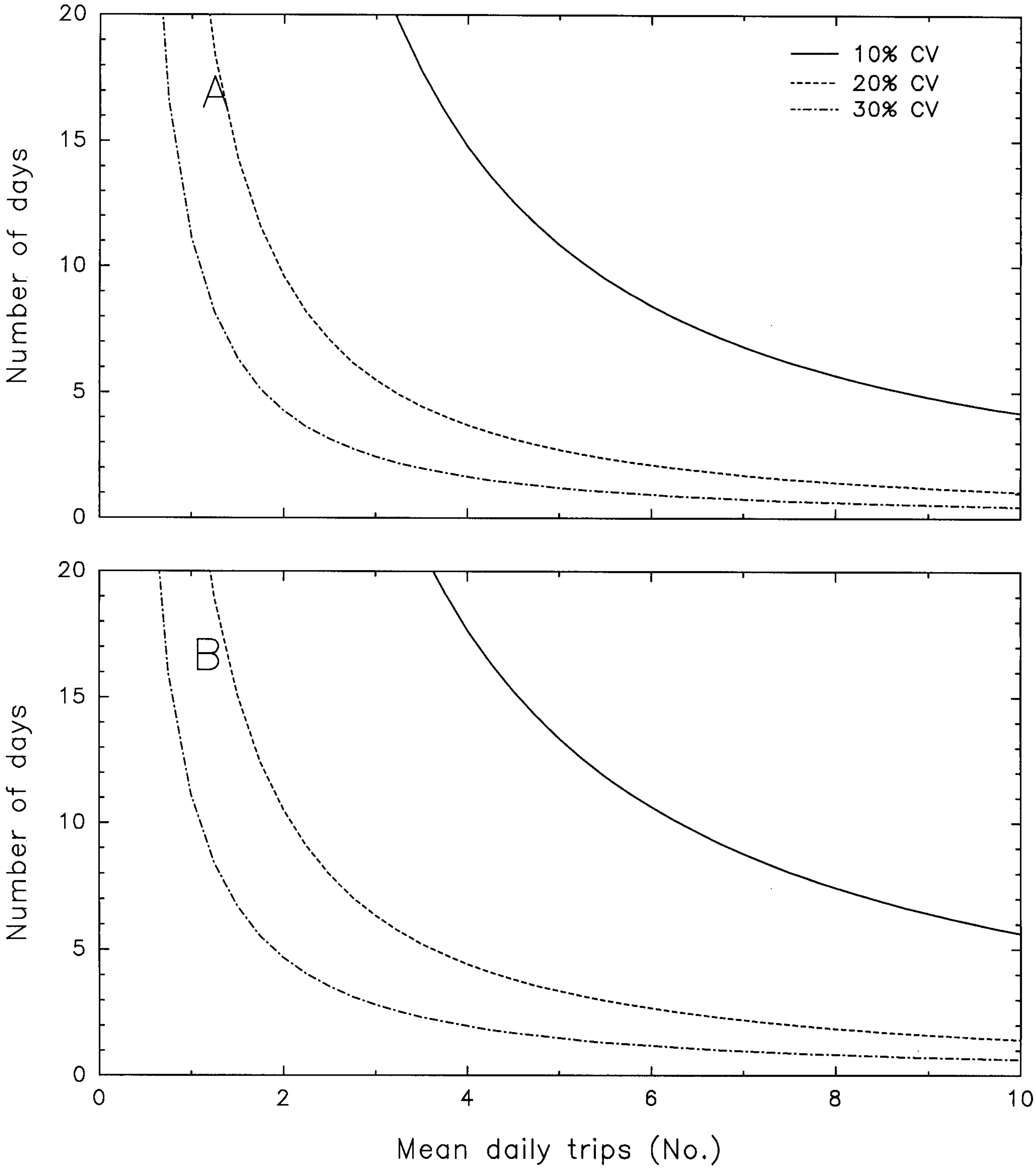

Figure 23.--Required sample size for estimating mean spring spearfishing activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

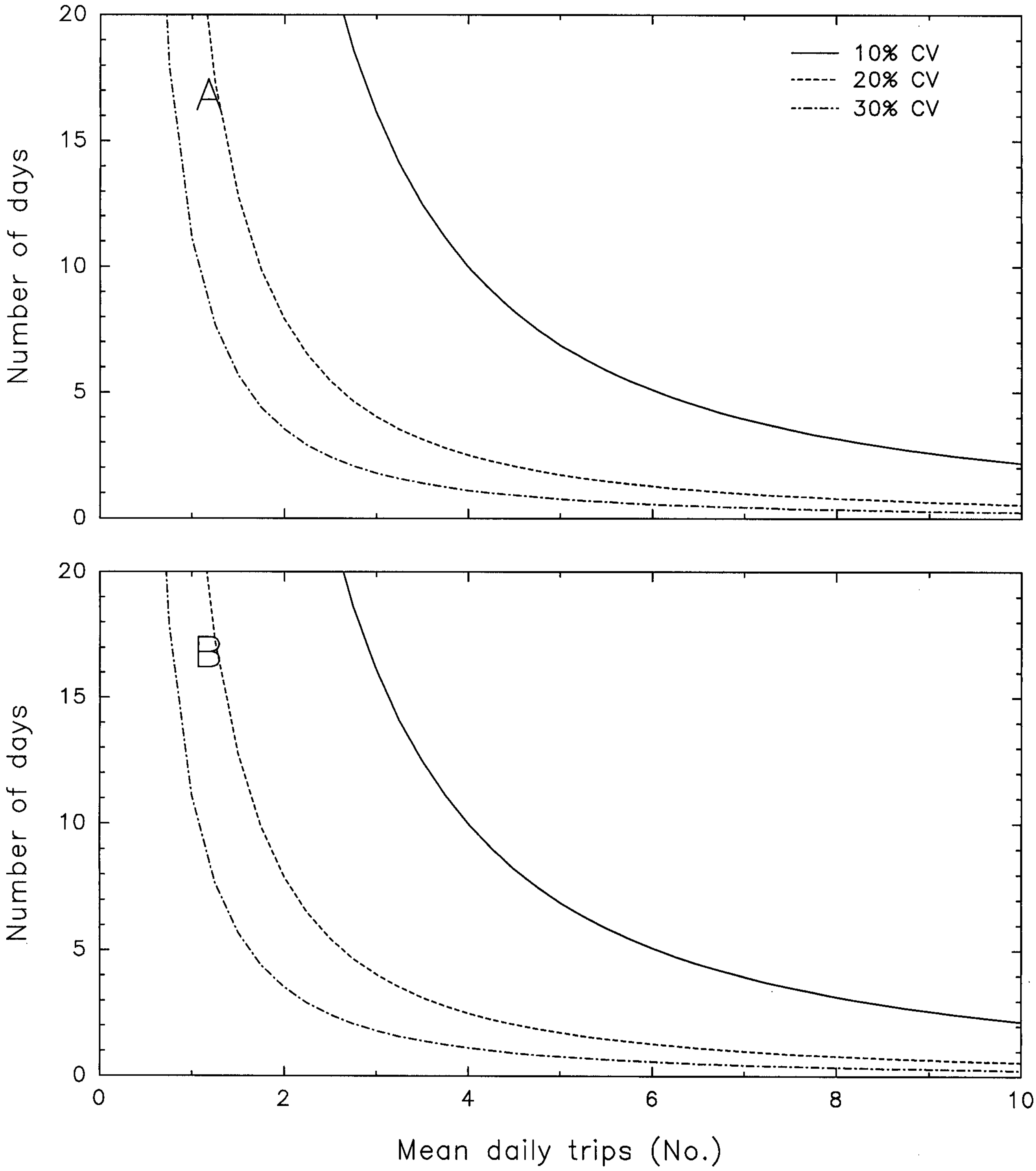

Figure 24.--Required sample size for estimating mean summer spearfishing activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

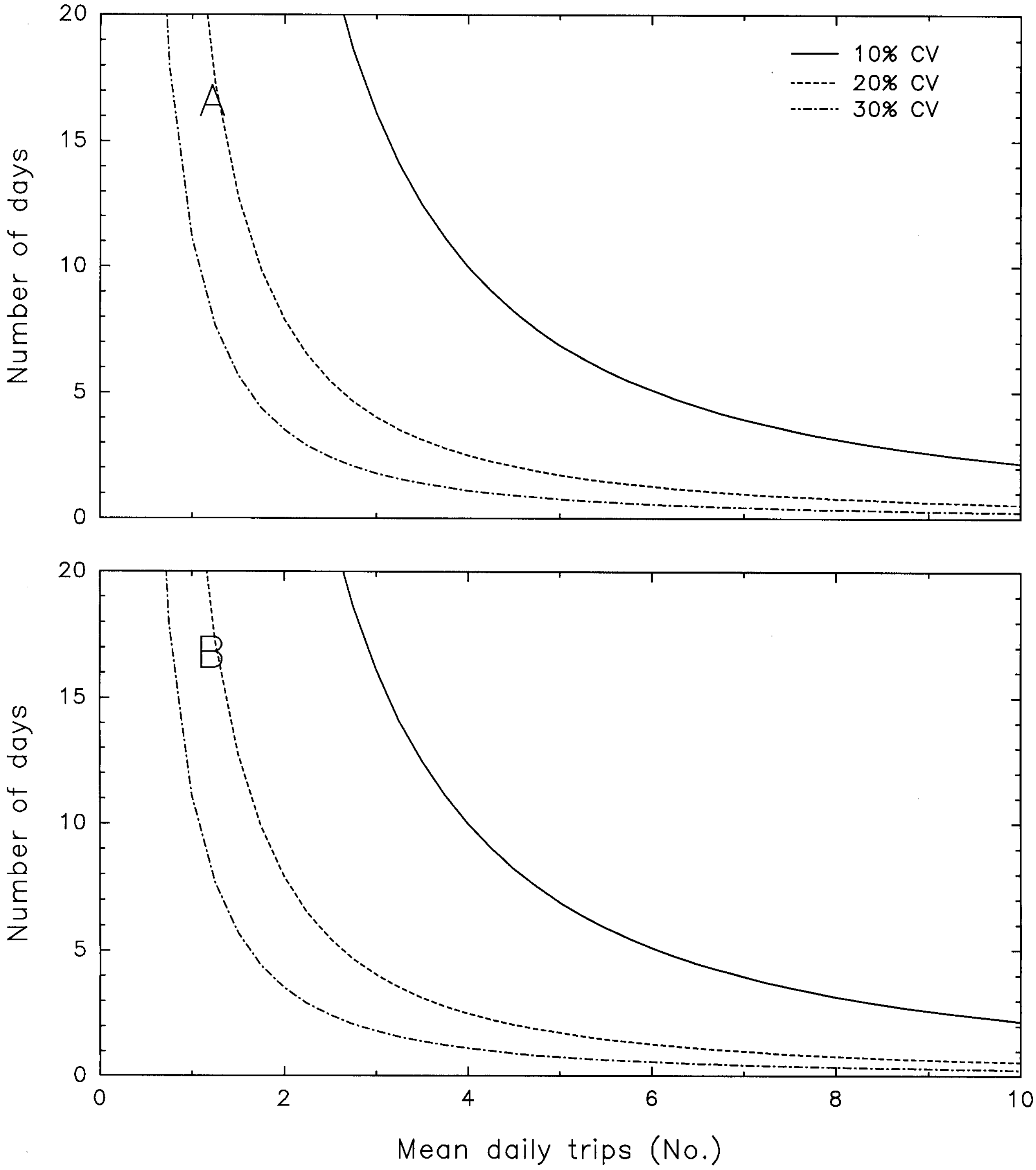

Figure 25.--Required sample size for estimating mean fall spearfishing activity around Guam at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays.

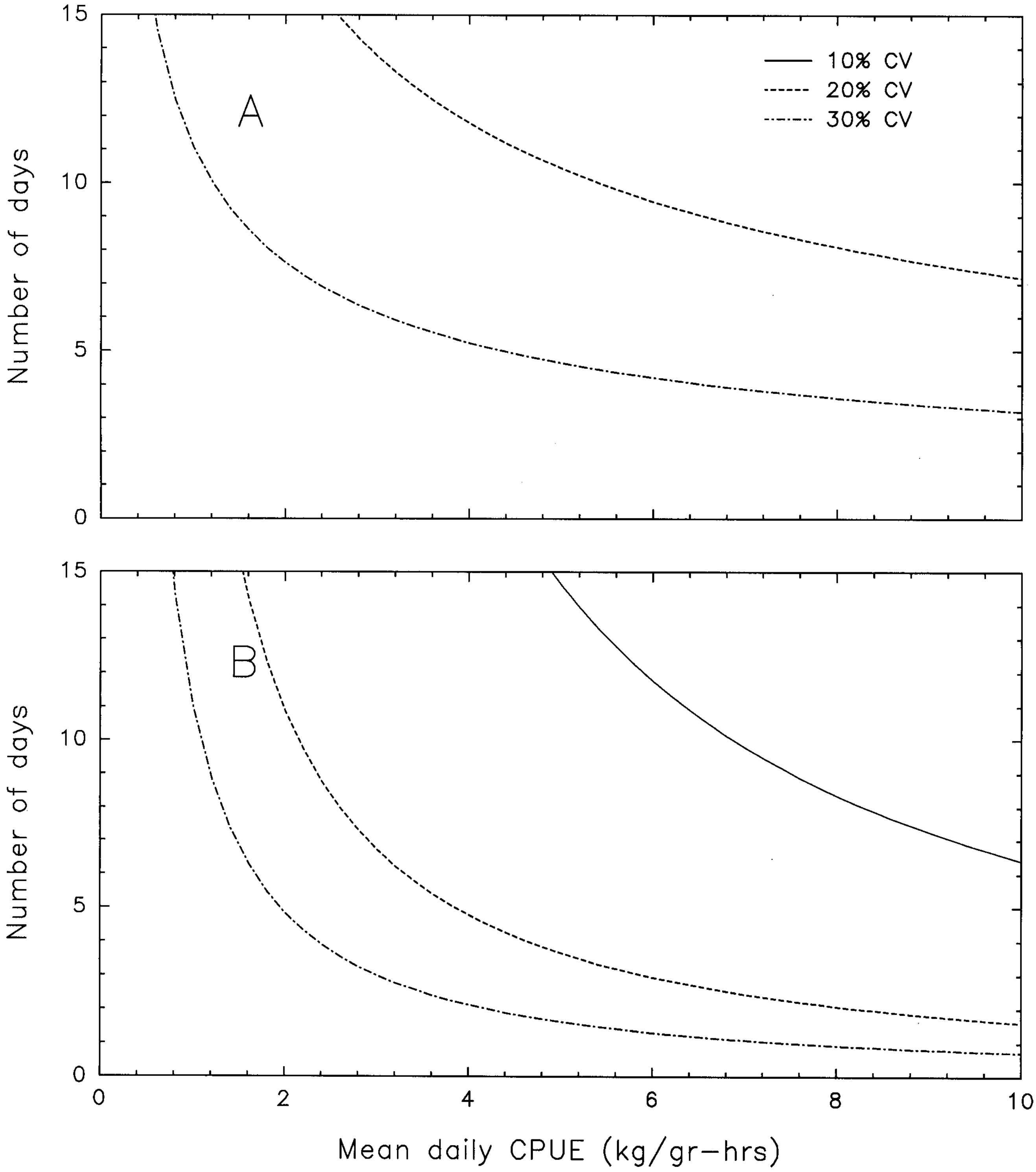

Figure 26.--Required sample size for estimating mean winter spearfishing CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

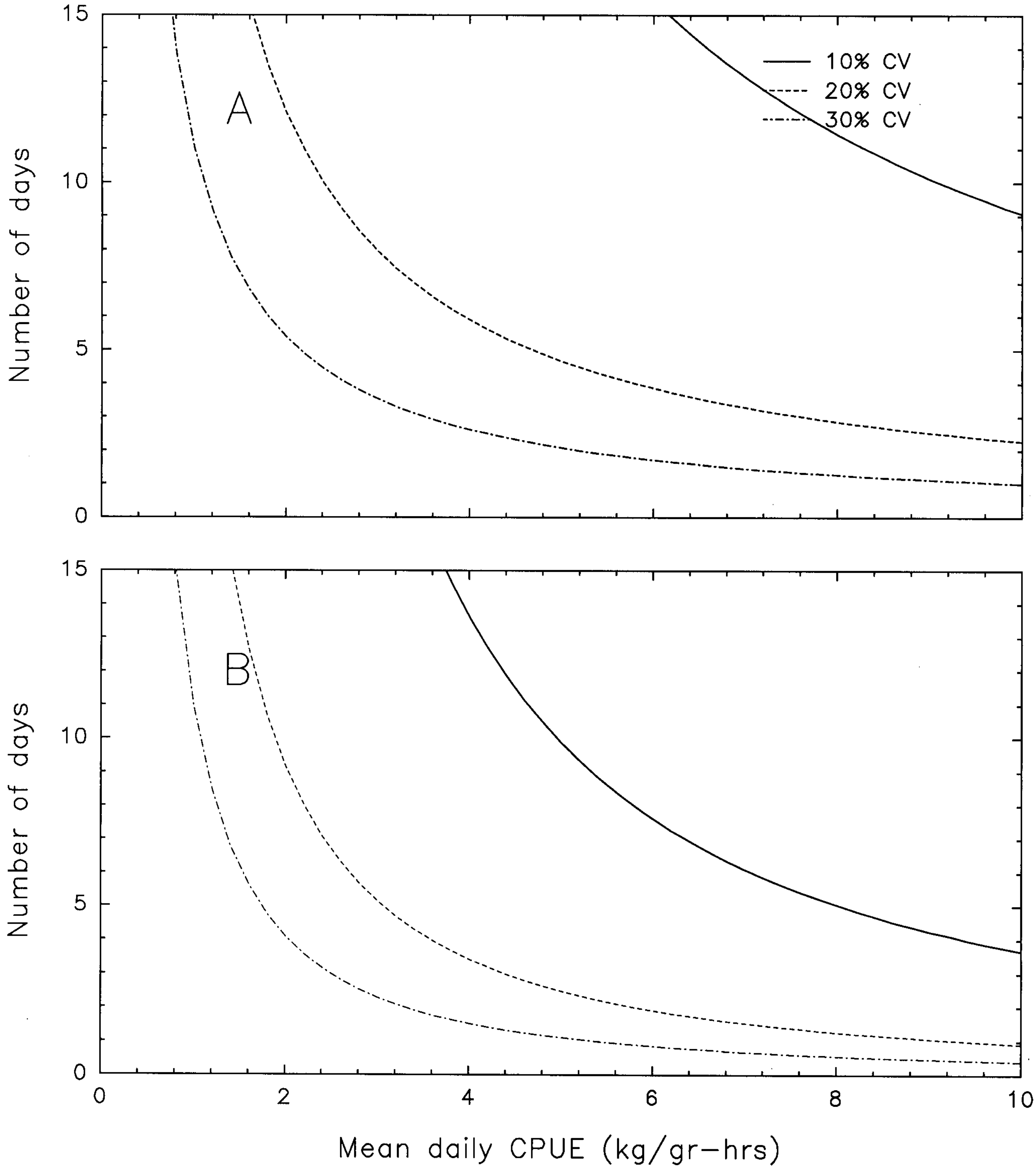

Figure 27.--Required sample size for estimating mean spring spearfishing CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

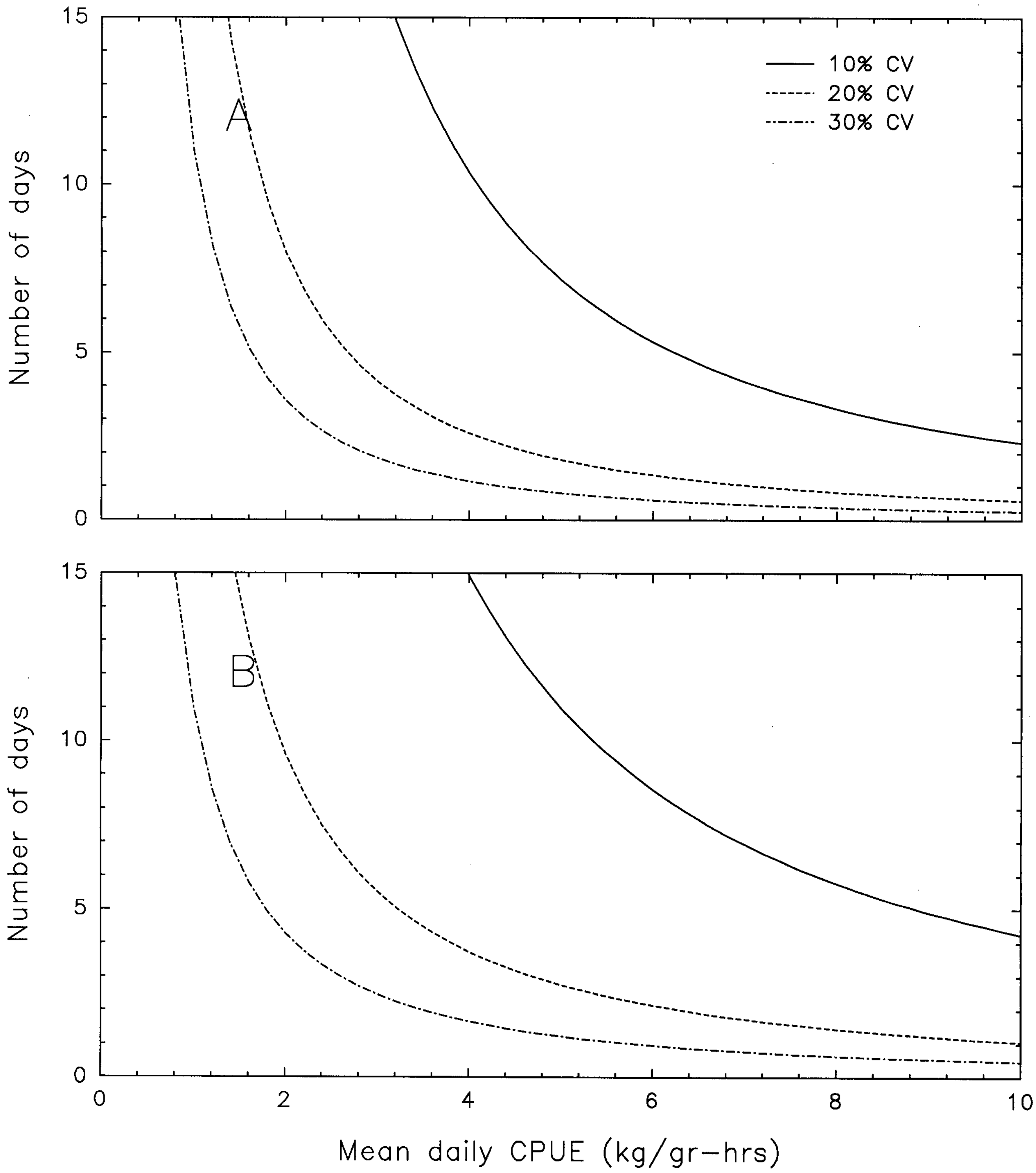

Figure 28.--Required sample size for estimating mean summer spearfishing CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

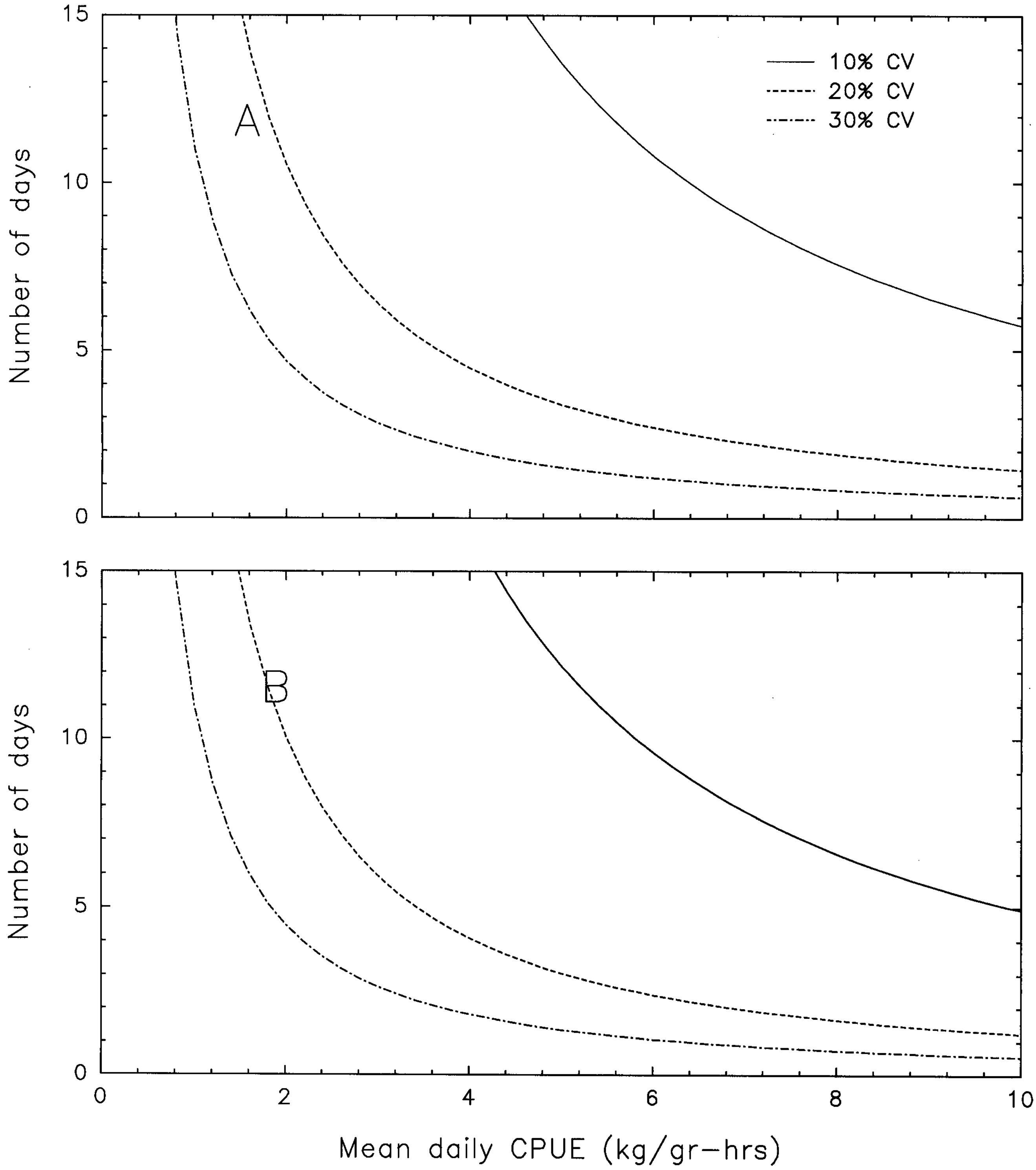

Figure 29.--Required sample size for estimating mean fall spearfishing CPUE at the 10, 20, and 30% CV levels for both weekdays and weekends or holidays with a ratio estimator.

Appendix A

Pauly (1979) suggested using the known growth of fish to make reasonable estimates of the growth parameters of stocks that have had limited investigation. One such method includes using the relationship between K and asymptotic size; another method uses an auximetric grid (growth measurement grid). Many authors noted that in a given fish species K increases as asymptotic size decreases, and from 126 species distributed over 978 stocks Pauly (1979) had devised the following relationship,

$$\log K = a - 2/3 \log(W_\infty) \qquad (1)$$

or

$$\log K = a - 2/3 \log(L_\infty^3) \ . \qquad (2)$$

Using growth parameters of similar species the intercept, 'a', can be determined in the above equation and thus K', estimated. Asymptotic length may be obtained by the relationship

$$L_\infty \approx 1.053 \ L_{max} \qquad (3)$$

which applies to fish which reach a length of about 50 cm.

The second method is related to the first method in that the relationship between K and asymptotic size is used. From the

Appendix A.--Continued.

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von Bertalanffy growth curve of fish weight the inflection point is given by

$$\frac{dwi}{dt} = \frac{4}{9} k (W_\infty) , \tag{4}$$

and results in the determination of parameter P as a function of K and W_∞; which is defined as

$$P \approx \log_{10}(K \cdot W_\infty) . \tag{5}$$

The value of P ranges from -0.70 for small Myctophidae to 5.79 for the basking shark, although within species P remains relatively constant. The feature of the growth performance index, P, is best demonstrated by transposition of the concept into a special grid called the auximetric grid. Axes of the grid consist of the values of W_∞ and K with both ranges covering normal-sized commercial fishes. Although no other age and growth methods were undertaken by the WIDA Project these provide alternative approaches for age and growth studies.

Appendix B

With the current offshore survey schedule of 6 WD and 6 WE/H per season the number of days needed to estimate mean island-wide participation and catch rates for each of day types is the very minimum necessary to obtain accurate results through stratified sampling of the three major boat basin. For each season 6 WD and 6 WE/H are randomly selected and randomly allocated between the three major launching sites. Because variance estimates are needed, a minimum of two survey days for each day type at each site is needed. As before, on each survey day fishing trips are tallied according to fishing method, day type, and launching site. Returning fishermen are randomly interviewed for catch and effort and biological information on their catches.

Thus, estimates of seasonal catch rates by fishing method and by type day were made with a ratio estimator. There were primarily two ways of applying the ratio estimator in a stratified design; the first method, the *separate* ratio estimator, was derived from the strata or ports sums and mathematically defined as

$$CPUE_{rat.s} = \frac{\sum_{h=1}^{n}\left(\sum_{i=1}^{n} y_{h_i}\right)}{\sum_{h=1}^{n}\left(\sum_{i=1}^{n} x_{h_i}\right)}\ , \qquad (1)$$

Appendix B.--Continued.

---

where y_{hi} is catch estimate from the *ith* interview in the *hth* stratum or launching site, and x_{hi} is the effort in gear hours from the *ith* interview in the *hth* stratum. The second method was a *combined* ratio estimator and expressed as

$$CPUE_{rat.c} = \frac{\sum_{h=1}^{n} N_h \bar{y}_h}{\sum_{h=1}^{n} N_h \bar{x}_h} = \frac{\sum_{h=1}^{n} \frac{N_h \sum_{i=1}^{n_h} y_i}{n_h}}{\sum_{n=1}^{n} \frac{N_h \sum_{i=1}^{n} x_i}{n_h}} , \tag{2}$$

where $\bar{y}_h$ is the mean catch and $\bar{x}_h$ is the mean effort in the *hth* stratum, and N_h is the number of daily trips for a fishing method in the *hth* stratum. The separate ratio estimator in Equation (2) would be valid if the number of days sampled in each stratum were equal. An alternate method for calculating the separate ratio estimator can be defined as

$$CPUE_{rat.c} = \frac{\sum_{h=1}^{n} \bar{N}_h \bar{y}_h}{\sum_{h=1}^{n} \bar{N}_h \bar{x}_h} = \frac{\sum_{h=1}^{n} \frac{\bar{N}_h \sum_{i=1}^{n_h} y_i}{n_h}}{\sum_{n=1}^{n} \frac{\bar{N}_h \sum_{i=1}^{n} x_i}{n_h}} , \tag{3}$$

where $\bar{N}_h$ is the seasonal mean number of daily trips out of the *hth* launching site. The separate ratio estimator utilizes a

Appendix B.--Continued.

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self-weighing factor which allows for varying sampling rates. Provided that daily sample size at each port is large enough, the overall the variance of Equation 2 can be estimated by the sum of the stratum variances and defined as

$$V(CPUE) = \sum_{h=1}^{n} s_h^2 = \sum_{h=1}^{n} \left(\frac{N_h - n_h}{n_h N_h} \right) \left(\frac{1}{\mu_h^2} \right) \frac{\sum_{i=1}^{n_h} (y_{h_i} - r_h x_{h_i})^2}{n_h - 1} , \quad (4)$$

where y_{hi} and x_{hi} are the catch and effort in the *hth* stratum and from the *ith* interview, respectively. Catch rate in the *hth* stratum was denoted as r_h; and N_h and n_h are the seasonal mean daily trips and number of trip interviews for a fishing method in the *hth* stratum, respectively. If the stratum population mean for μ_{xh} is unknown then $\overline{x^2}_h$ would be used to approximate the population mean in the above equation (Mendenhall et al., 1971).

Estimates of seasonal mean daily fishing trips and variance from the three major launching sites can be determined from the sum of the stratum means and variances for each fishing method and day type. Seasonal estimates are determined mathematically as

$$\bar{a}_j = \sum_{h=1}^{n_{j_h}} \bar{a}_{j_h} \quad (5)$$

Appendix B.--Continued.

and

$$s_j^2 = \sum_{h=1}^{n_{j_h}} s_{j_h}^2 \,, \tag{6}$$

where $n_{\underline{j/h}}$ is the number of stratum in the *jth* season. And $\bar{a}_{j/h}$ and $s^2_{\underline{j/h}}$ are the mean number of trips and variance in the *jth* season in the *hth* strata.

The following table is an example of a stratified three-port ratio estimator design to estimate weekday seasonal trolling catch rate. With a sampling scheme of 6 days per season and randomly allocated equally among the three ports, this table shows the total trolling fishing trips, sampled trolling trips, catch rates, catch and effort from each port from a total of possible 68 weekdays.

Sampling day	Port	Total trolling trips	Trolling trips sampled	Mean daily catch rate (kg/gr-hr)	Total daily catch (kg)	Total daily effort (gr-hr)
1	Agana	40	20	2.2	308	140
2	Merizo	10	2	3.1	34	11
3	Agat	36	16	1.8	216	120
4	Merizo	8	2	2.5	50	20
5	Agat	28	14	1.5	158	105
6	Agana	30	25	1.9	285	150

Appendix B.--Continued.

From the 79 interviewed trips during the 6 survey days, seasonal catch rate for the three sampled sites combined was calculated as

$$\bar{r}_j = \frac{\sum_{h=1}^{3} \bar{N}_{j_h} \bar{C}_{j_h}}{\sum_{h=1}^{3} \bar{N}_{j_h} \bar{f}_{j_h}} = \frac{\sum_{h=1}^{3} \dfrac{\bar{N}_{j_h} \sum_{i=1}^{n_h} C_{j_{h_i}}}{n_{j_h}}}{\sum_{h=1}^{3} \dfrac{\bar{N}_{j_h} \sum_{i=1}^{n_h} f_{j_{h_i}}}{n_{j_h}}} \tag{7}$$

$$= \frac{(35)(13.18) + (32)(12.47) + (9)(21.0)}{(35)(6.44) + (32)(7.5) + (9)(7.75)}$$

$$= 1.961\ kg/gr\text{-}hr$$

and variance as

$$V(r_j) = \sum_{h=1}^{3} V(r_{j_h})$$

$$= \sum_{h=1}^{3} \left(\frac{N_{j_h} - n_{j_h}}{n_{j_h} N_{j_h}}\right)\left(\frac{1}{\bar{f}^2_{j_h}}\right) \frac{\sum_{i=1}^{n_{j_h}} (c_{j_{h_i}} - r_{j_h} f_{j_{h_i}})^2}{n_{j_h} - 1} \; . \tag{8}$$

$$= (0.0218) + (0.02101) + (1.8306)$$

$$= 1.8734$$

Seasonal catch rate, r'_j is determined by the weighted average of mean WD and WE/H catch rates as

$$r'_j = \frac{N_{j_{WD}}}{N_j} r_{j_{WD}} + \frac{N_{j_{WE/H}}}{N_j} r_{j_{WE/H}} \; , \tag{9}$$

Appendix B.--Continued.

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where $N_{j/WD}$ and $N_{j/WE-H}$ are the number WD and WE/H days, respectively and N_j is the total number of days in the *jth* season. $\bar{R}_{j/WD}$ and $\bar{R}_{j/WE-H}$ are mean seasonal catch rates of the three-boat launching sites combined for both WD and WE/H, respectively. Similarly, seasonal variance can be estimated by weighted average of the WD and WE/H seasonal variances and shown as

$$V(r'_j) = \left(\frac{N_{j_{WD}}}{N_j}\right)^2 V(r_{j_{WD}}) + \left(\frac{N_{j_{WE/H}}}{N_j}\right)^2 V(r_{j_{WE/H}}) \ , \qquad (10)$$

where $V(R_{j/WD})$ and $V(R_{j/WE-H})$ are the seasonal variance estimates for both WD and WE/H, respectively.

Seasonal estimates of mean daily trolling trips and variance can be calculated with traditional methods. Strata means and variances are independently calculated and summed over the three strata for daily seasonal estimates. Seasonal mean and variance are determined as

$$a_j = \sum_{h=1}^{3} \bar{a}_{j_h} = \frac{70}{2} + \frac{64}{2} + \frac{18}{2} = 76.0 \qquad (11)$$

and as

Appendix B.--Continued.

$$s_j^2 = \sum_{h=1}^{3} s_{j_h}^2 = 50 + 32 + 2 = 84. \qquad (12)$$

Similarly, overall seasonal mean and variance of number of daily trips can be estimated by the weighted average of WD and WE/H estimates with the number of respective day types as weights.

Stratified sampling of the three major launching sites will cover nearly all of the island's offshore trolling and bottomfishing activities and nearly 90% of the spearfishing. Stratified sampling will provide a better account of the island-wide offshore fishery by monitoring all three major boat launching sites.